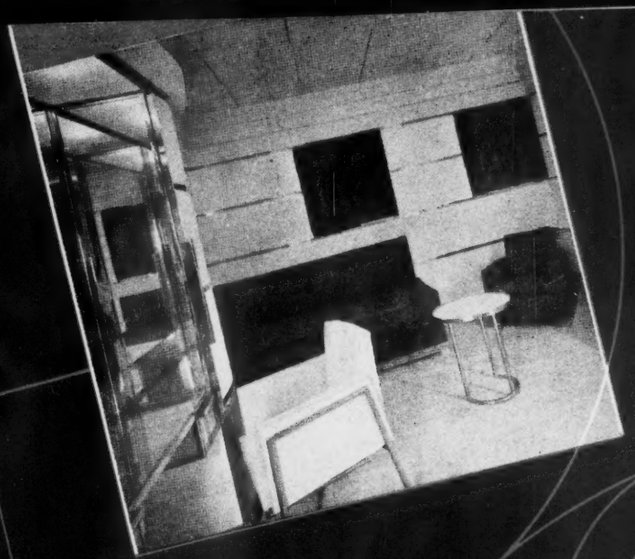
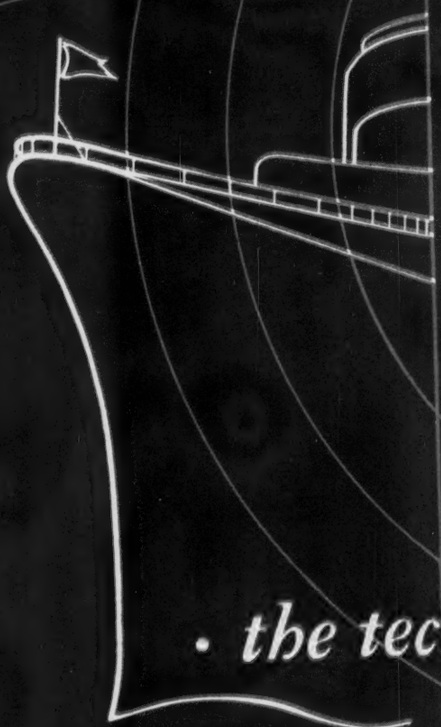




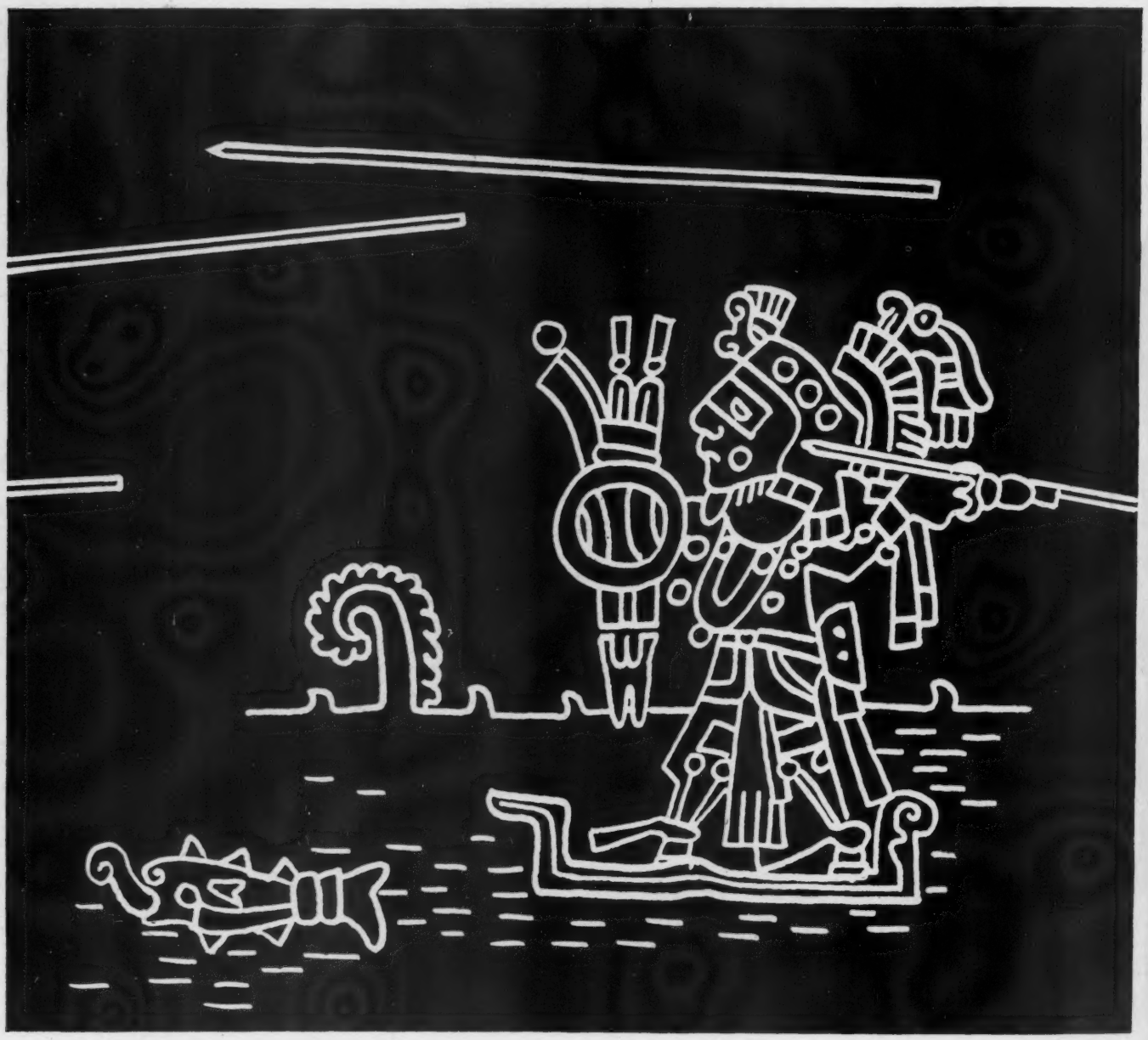
. the tech engineering news

may

HOW TO MAKE AN ARM GROW

A human arm can throw a spear only so far. But some ancient genius of an engineer figured out that, by employing a throwing stick, which the Aztecs called *atlatl,* the lever of the human arm —and the distance achieved—could be extended, with quite pointed results for an enemy.

Specifying molybdenum in steel is something like using an *atlatl.* For molybdenum extends the usefulness of good steel. By providing good hardenability at low cost, molybdenum steels permit modern engineers to save weight—and costs—in design. It pays to specify molybdenum.

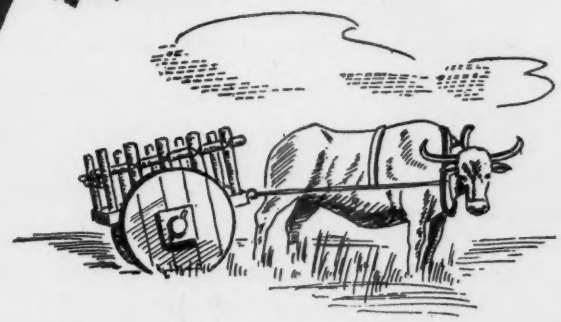


MOLYBDIC OXIDE—BRIQUETTED OR CANNED • FERROMOLYBDENUM • "CALCIUM MOLYBDATE"
CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.

Climax Molybdenum Company
500 Fifth Avenue · New York City

MOLY

Be a better engineer- know TIMKEN BEARINGS



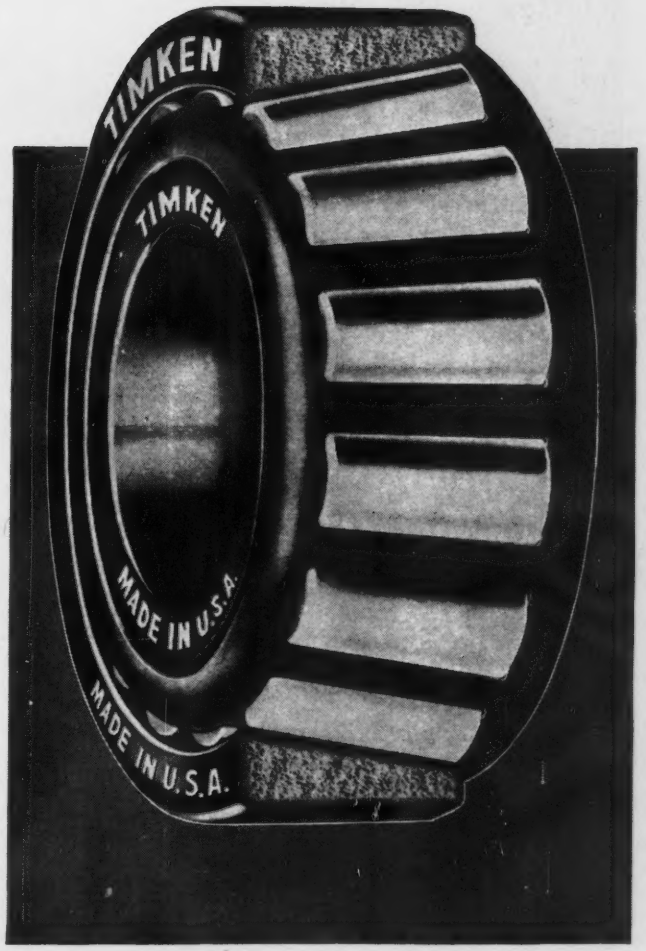
A thorough understanding of the design and application of Timken Tapered Roller Bearings will enable you to solve at least 90% of the bearing problems you are ever likely to encounter when you begin your engineering career after graduation.

When primitive man first made a hole in a crude wooden wheel and slipped it over a wooden axle he achieved the first function of a bearing — support.

Support for wheels, shafts, gears and other rotating parts still is the primary purpose of bearings, but several other vital bearing requirements are needed in modern equipment.

Ability to carry radial loads, thrust loads or both together in any combination is one of the most important of these. Ability to hold moving parts permanently in alignment is another. Then of course there is the reduction of friction, although this quality is common, in varying degrees, to all anti-friction bearings.

The tapered roller bearing was introduced by The Timken Roller Bearing Company nearly 50 years ago and today is universally used throughout industry and transportation. Every genuine Timken Bearing is unmistakably identified by the trade-mark "TIMKEN" stamped on cup and cone.



TIMKEN
TRADE-MARK REG. U. S. PAT. OFF.
TAPERED ROLLER BEARINGS

THE TIMKEN ROLLER BEARING COMPANY, CANTON 6, OHIO

Massachusetts Institute of Technology
CAMBRIDGE, MASSACHUSETTS

THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY
offers the following Professional Courses

SCHOOL OF ARCHITECTURE AND PLANNING

Architecture

City Planning

SCHOOL OF SCIENCE

Chemistry
Food Technology
Food Technology — Five Year Course
General Science
Geology
Mathematics
  Options: Pure and Applied Mathematics
           Industrial Statistics
Physical Biology
Physics
Quantitative Biology

SCHOOL OF ENGINEERING

Aeronautical Engineering

Building Engineering and Construction
  Options: Heavy Construction
           Light Construction

Business and Engineering Administration
  Courses: Based on Physical Sciences
           Based on Chemical Sciences

Chemical Engineering

Chemical Engineering Practice

Civil Engineering
  Group Electives:
    Sanitary Engineering
    Transportation Engineering
    Hydraulic Engineering
    General Engineering

Economics and Engineering
  Options: Human Relations
           Industrial Relations

Electrical Engineering
  Options: Electric Power
           Illumination Engineering
           Electrical Communications
           Electronic Applications

Electrical Engineering
  Co-operative Course

General Engineering

Marine Transportation

Mechanical Engineering
  Options: General Mechanical Engineering
           Engineering Science
           Automotive Engineering

Mechanical Engineering-
  Co-operative Course

Metallurgy
  Options: Metallurgy
           Mineral Dressing

Meteorology

Naval Architecture
and Marine Engineering

The duration of each of the above undergraduate Courses is four academic years, with the exception of Architecture, Food Technology (Five Year Course), Physical Biology, and the Co-operative Courses in Electrical Engineering and in Mechanical Engineering, which extend over a period of five years. In addition to the Bachelor's degree, the above five year courses, with the exception of Architecture, lead also to the Master's degree.

Graduate study, leading to the Master's and Doctor's degrees, is offered in Ceramics and in most of the above professional Courses.

A five year Course is offered which combines study in Engineering or Science, and Economics. This leads to the degree of Bachelor of Science in the professional field, and to the degree of Master of Science in Economics and Engineering or Economics and Natural Science.

For information about admission, communicate with the Director of Admissions. The Catalogue for the academic year will be sent free on request.

What are the most expensive ingredients in a railroad car?

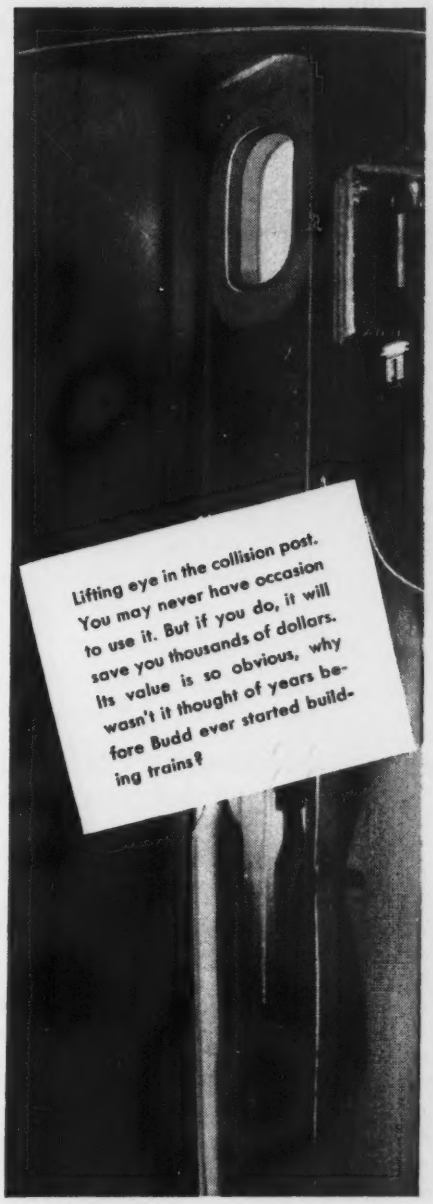
In our opinion they are tradition and habit. For they put brakes on creative thinking . . . resist change . . . cling to the past. They can turn out a cheap car quickly, but all you get is a new car, not a modern one. In the long run, when all the costs on maintenance and lost availability are added up, it can prove a very expensive "bargain."

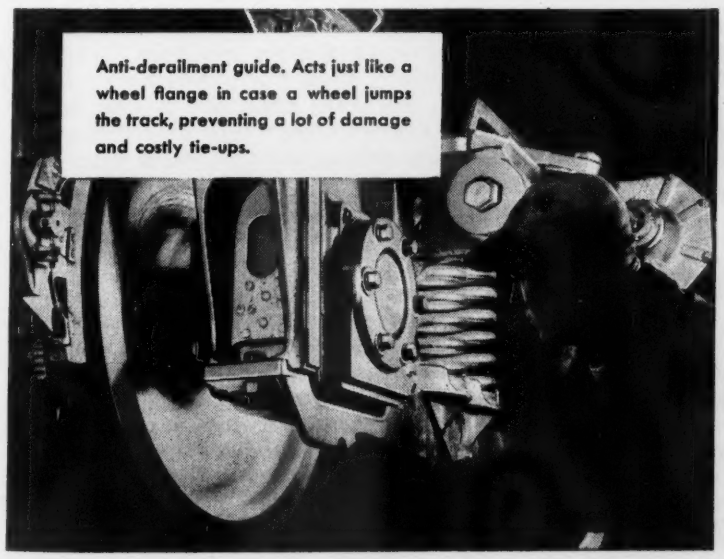
At Budd, every design, every item of equipment, every structural requirement, is the result of a challenge to improvement. There are three objectives. A car that invites passengers to ride in it. A safer car. A car that provides the greatest possible economy of time and money in operation.

From the standpoint of profitable operation, maintenance can be the key factor. While available records show wide variations in maintenance accounting methods, all indicate that quality and stamina built into a car repay their initial cost many times in saving of maintenance expense.

How successfully Budd is attacking these costs is found in the experience of an eastern railroad which took delivery of forty Budd cars last Summer. *Not a single Budd-built, stainless steel car has failed to complete every schedule.*

The Budd Company, Philadelphia.


Lifting eye in the collision post. You may never have occasion to use it. But if you do, it will save you thousands of dollars. Its value is so obvious, why wasn't it thought of years before Budd ever started building trains?


Anti-derailment guide. Acts just like a wheel flange in case a wheel jumps the track, preventing a lot of damage and costly tie-ups.

Lifetime maintenance cost of a railway car *exceeds its purchase price*

Budd

Briefing the News . . .

Electron Beam Is Made Visible . . .

AN electron beam has been made visible by its own light in the General Electric Research Laboratory. According to Dr. C. G. Suits, G-E Vice-President and Director of Research, this is believed to be the first time this effect has been observed.

The new observations have been made in the 70,000,000-volt synchrotron, a new type of atom smasher, built in the Laboratory under a contract with the Office of Naval Research. It has been shown that visible light is literally given off from the moving electrons. Because of the dangerous X-rays emitted by the synchrotron, it is not possible to approach closely while in operation, but by means of a mirror, scientists can watch from behind a thick concrete wall. Inside the doughnut-shaped vacuum tube in which the electrons circle, a brilliant bluish-white spot appears. This is from light beamed forward from the electrons, tangent to their circular orbit.

Though the effect is mainly of theoretical interest, the visibility of the electrons will be of use to scientists developing larger machines in that they can locate accurately, within the vacuum enclosure, the tiny beam as it reaches higher energies.

Previously, electrons have been detected visually only by indirect means, it was pointed out. When they strike a material such as zinc sulfide or pass through certain gases, a glow results, but such light does not come from the bombarding electrons themselves. Also, with a laboratory device known as the Wilson cloud chamber, the path of an electron appears as a thread-like trail of fog, but this again is indirect. Scientists say this method is much like telling where a boat has travelled by aerial observation of the wake it leaves behind.

In 1944 two Russian physicists, D. Iwanenko and I. Pomeranchuk, pointed out that radiation should come from the electrons moving in circular orbits in a betatron, another form of atom-smasher, related to the synchrotron. This effect, they said, would impose a limit on the simple betatron. Over about a hundred million volts, the electrons would radiate energy away as fast as they receive it unless proper compensation were made.

Calculations indicated that such an effect should be observed from the electrons in the 100,000,000-volt betatron in the G-E Research Laboratory and that some of the radiation should be of visible light. However, construction of the doughnut, which is lined with silver, makes it opaque, thus preventing any observation. Then it was thought that perhaps some radiation of very short radio waves might be detected, using methods developed for wartime radar. But again the search was unsuccessful. Dr. J. S. Schwinger, of Harvard University, calculated that while there might be some slight emission in the microwave region, the maximum amount of energy would come in the shortest wavelengths, either visible light or the longer invisible waves of infrared.

The synchrotron doughnut, however, is lined with a transparent layer which is electrically conducting like the silver layer and carries away unwanted electrical charges as they accumulate. A laboratory assistant, however, happened to notice a curious spot of light inside the doughnut while the synchrotron was operating. After checking to assure that everything was working properly, the physicists in charge of the project determined that this was actually radiation from the electrons themselves as they moved around in their circular path. An intense magnetic field, from the large electromagnet which surrounds the doughnut, keeps them to this orbit.

Electron light travels out in a beam half a degree in diameter, tangent to the orbit. It comes out ahead of the electrons. Thus, an observer looking at the doughnut from a point in the plane of the orbit, sees light from the electrons approaching him, but cannot see the light in any other part of the tube. Because of the curvature of the doughnut, the spot is distorted at present. Dr. Herbert C. Pollock, who has charge of the synchrotron project, and his associates, Drs. R. V. Langmuir and Frank R. Elder, are preparing a modified doughnut with a flat quartz window through which the effect may be better seen. This will permit any part of the radiation that may fall in the invisible ultraviolet part of the spectrum to be photographed as quartz, unlike glass, is transparent to these rays.— *General Electric.*

A New Shooting Star . . .

A new jet-propelled P-80 Lockheed Shooting Star fighter plane with greater firepower and more resistance to battle damage has recently been developed. The AAF has just purchased 134 more of these very high speed craft for $8,681,960, bringing to 1,066 the number of P-80's delivered or on order.

Known as the P-80-B, the new Shooting Stars are believed to have the greatest firepower of any jet fighter in the world. Structural improvements to the plane include thicker skin and stronger bulkheads in the nose section to provide a sturdier base for the Shooting Star's armament and the use of stainless steel around the engine for greater fireproofing against enemy attacks.

Pilot ejector seats will shoot the pilot clear of the plane in case of trouble, and air conditioning in the pressurized cockpit will maintain comfortable temperatures of between 70 and 80 degrees. Radio masts and antenna wires have been enclosed in the new P-80 for the first time on any airplane. Water injection in the Allison-built super turbo-jet engine increases take-off and climb performance materially. — *Army Ordnance.*

Respirator for Arctic Climates . . .

A device for retaining body heat exhaled with the breath in extremely cold climates has been tested by Army Ground Forces "Task Force Frigid" at Fairbanks, Alaska, and also in the Antarctic. Known as the "heat regenerating respirator," this Quartermaster-designed equipment demonstrated a high degree of efficiency in tests conducted under subzero temperatures in weather chambers at the Quartermaster Climatic Research Laboratory at Lawrence, Mass.

Metal wool absorbs the heat contained in the vapor expired by the breath and releases this heat to the inspired air. In this way, the upper respiratory tract and lungs of the wearer are protected against extremely cold air and body heat is conserved. At a temperature of 40 degrees Fahrenheit below zero, a person breathing a volume of 500 cubic centimeters and with a respiratory rate of 15 per minute may lose as much as 480 calories in 24 hours while at rest. Under moderate exercise the loss for the same person would be increased to 1,730 calories in 24 hours.— *Army Ordnance.*

COLUMBIA'S technical staff

explores potentials of alkalies

Columbia Laboratories, Barberton, Ohio

As a leading producer of alkalies and related chemical products, Columbia has been engaged continually in revealing their vast potentials. Modern facilities, such as the laboratory pictured above, provide skilled chemists, physicists and chemical engineers with the tools they need to discover new chemical products . . . to develop better, more efficient manufacturing methods . . . to find new ways for others to utilize the inherent values of alkalies and their derivatives.

COLUMBIA'S TECHNICAL STAFF COMPRISES—

RESEARCH—developing new products and new applications for both established and new products; improvement of processes.

DEVELOPMENT—operating pilot plants—the transition stage from laboratory to practical application; consultants on special production problems.

TECHNICAL SERVICE—assisting customers in handling and utilizing products to best advantage.

MARKET RESEARCH & DEVELOPMENT—ascertaining potentials of new markets for all products, introducing new products and developing new uses of all products.

JOIN

COLUMBIA CHEMICALS

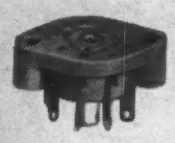
PITTSBURGH PLATE GLASS COMPANY

COLUMBIA CHEMICAL DIVISION

FIFTH AVENUE at BELLEFIELD, PITTSBURGH 13, PENNSYLVANIA · Chicago · Boston · St. Louis
Pittsburgh · New York · Cincinnati · Cleveland · Philadelphia · Minneapolis · Charlotte · San Francisco

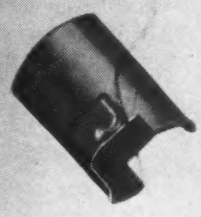
NEW

XOA Socket with XOS-3 Shield and Shield Base

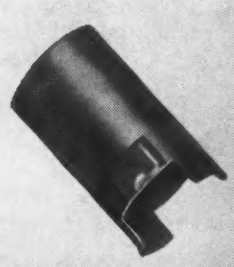


XOA Socket

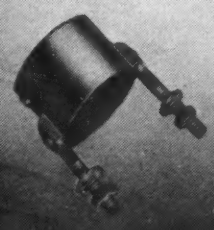
XOR Socket



XOS-1 Shield for $1\frac{3}{16}$" high tube body (6AK5 type)



XOS-3 Shield for 2" high tube body (OA2 type). Also available: XOS-2 for 1 ½" high tube body (6C4 type)



Shield Base for XOS-1, XOS-2 or XOS-3

SOCKETS AND SHIELDS...

for miniature button base tubes

These new National sockets are of mica-filled natural molded Bakelite with silver-plated beryllium-copper contacts — designed for maximum dependability and adaptability. The contacts — either axially or radially mounted and removable for replacement — provide short leads and low inductance so vital to ultra-high frequency design. Sockets are built to JAN specifications — can be used with or without shields.

Made in three sizes to accommodate the various sizes of miniature tubes, the shields are of nickel-plated brass, with cadmium-plated phosphor bronze spring to provide correct tension to hold both tube and shield in place regardless of angle or vibration. Shield bases are of nickel-plated brass, with two 4/40" spade bolts mounting both socket and shield base.

You'll find hundreds of other parts, both new and old, to improve your apparatus in the new 1947 National Catalog.

National NC EST. 1914

NATIONAL

COMPANY, INCORPORATED

MALDEN, MASS.

TIME RADIO PRODUCTS

The TECH ENGINEERING NEWS

PROFESSIONAL JOURNAL OF THE UNDERGRADUATES

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Volume XXVIII, No. 8

MAY, 1947

IN THIS ISSUE

317 TWO-MILLION-VOLT X-RAYS IN THE TREATMENT OF CANCER BY RICHARD W. SPENCER, '49

319 GAS TURBINES BY WILLIAM HAWTHORNE, Associate Professor of Mechanical Engineering

323 THE BIRTH OF THE PLANETS BY PETER B. NEIMAN, '47

324 PHYTOHORMONES BY HARRISON C. WHITE, '50

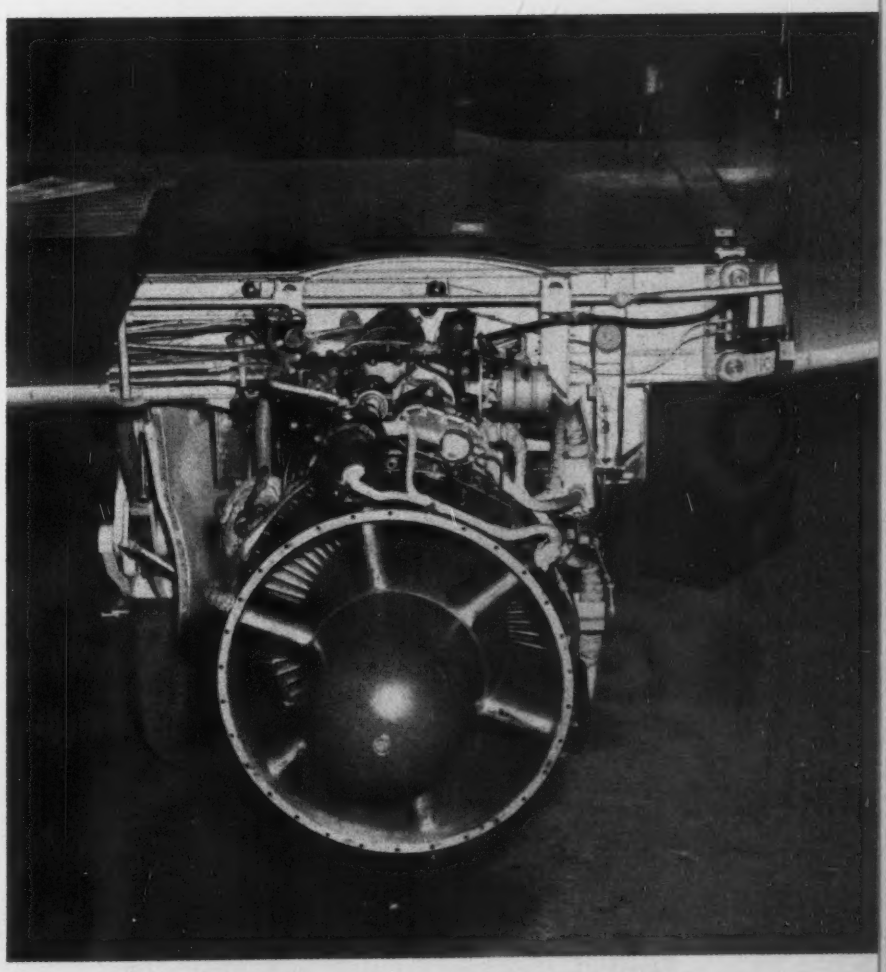
329 THE ROYAL MAIL SHIP *QUEEN ELIZABETH* BY GEORGE SWALLOW, '48

FEATURES

312 BRIEFING THE NEWS

334 CAN YOU DO IT?

335 THE DRAGON'S DEN



TITLE PAGE

***A forward view of one of the two F.2 jet propulsion engines installed in the Gloster* Meteor**

MEMBER OF THE ENGINEERING COLLEGE MAGAZINES ASSOCIATED

Published monthly during the school year at Walker Memorial, Cambridge 39, Massachusetts, by the undergraduates of the Massachusetts Institute of Technology. Entered as second class matter, at the Post Office, June 1, 1920, at Boston, Mass. under the Act of March 3, 1879.

Copyright 1947 by The Tech Engineering News.

Subscription per year $1.50. Foreign $1.75. One copy 25 cents.

The M. I. T. three-million-volt X-ray generator shown with steel pressure tank removed

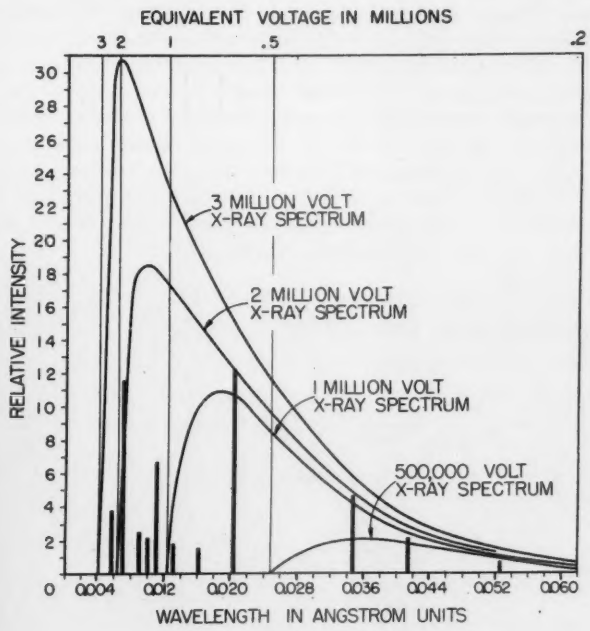
Electrical Engineering Department

Two-Million-Volt X-Rays in the Treatment of Cancer

By RICHARD W. SPENCER, '49

THE past few years have seen a great deal of development in radiation therapy for the treatment of malignant tumors. One of the more promising is the experimentation with x-rays of several million volts in the treatment of deep tumors.

The object of any kind of radiation treatment of tumors is to destroy the tumor with as little injury as possible to adjacent healthy tissue and to the skin, which is particularly sensitive to x-ray radiation. This is often difficult, particularly in the case of deep tumors. With ordinary x-rays for deep therapy it is often the case that the dose of radiation given a deep tumor is determined by the maximum dose the skin or other tissues can tolerate rather than by the optimum dose needed to kill the cancer.



Electrical Engineering Department

Figure 1. Comparison of the continuous Roentgen-ray spectrum produced by three-, one-, and half-million-volt electrons with the gamma-ray line spectrum emitted by radium in equilibrium with its products

Conventionally available x-rays produced by 200 kv. suffer considerable attenuation and misdirection due to scattering before they reach the site of a deep tumor. While these difficulties can be alleviated by proper choice of treatment distance, field size, number of portals (areas of skin) through which the rays pass in cross-firing at the tumor, etc., far more satisfactory results may become possible with supervoltage radiation, with voltages of from one to four million volts. This is the subject of research now going on in M. I. T.'s high-voltage laboratories.

The spectral distribution of x-rays is a function of the voltage used in their production. For each voltage of the electrons striking the target there is a definite minimum wavelength limit to the radiation spectrum which is produced. X-rays of this minimum wavelength occur when electrons lose all their energy in a single collision with the target. This minimum wavelength λ_0 can be computed from the Planck-Einstein relation

$$eV = hc/\lambda_0,$$

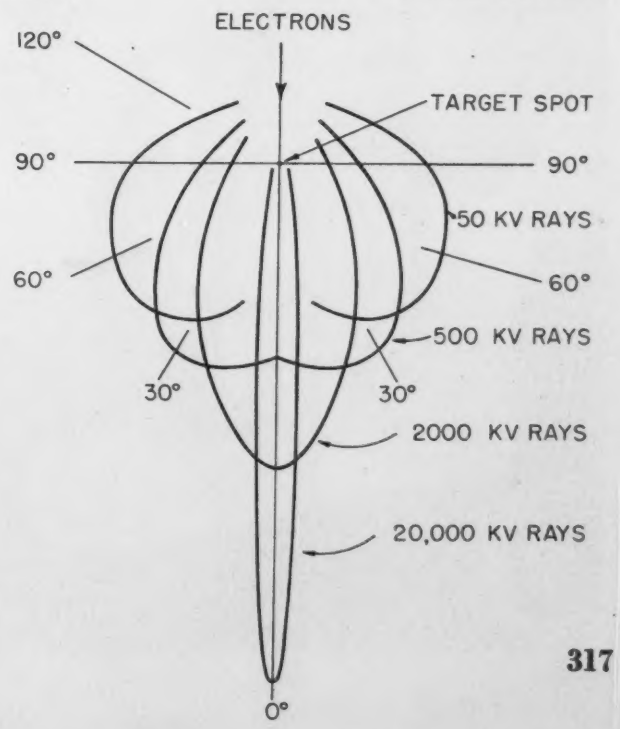
where e is the charge on an electron, V is the acceleration voltage, h is Planck's constant, and c is the velocity of light. For one-million-volt rays, $\lambda_0 = 0.0124$ Å, and for two-million-volt radiation, $\lambda_0 = 0.0062$ Å, where one Angstrom unit, Å, is 1×10^{-10} meters.

Most of the electrons lose their energy not in one collision, but in a series of collisions with the target, producing a continuous spectrum of ionizing radiation. Such spectra, calculated by Kramers' formula, are shown in figure 1. The wavelength of maximum intensity is at about 1.4 λ_0. This maximum corresponds to the most probable amount of energy lost in any single collision between an electron and an atom of the target. Some radiation is produced throughout the range of the softer x-rays and even in the ultra-violet, but most of this is absorbed by the target.

Increasing the voltage tends to move the spectrum of figure 1 toward the shorter wavelengths and increases the total radiant energy produced by given power on the target. The decrease in wavelength causes an increase in penetration because of decreased scattering.

Figure 2. Diagrammatic representation of the spatial intensity distribution of Roentgen rays as a function of the voltage of the impinging electrons

Electrical Engineering Department



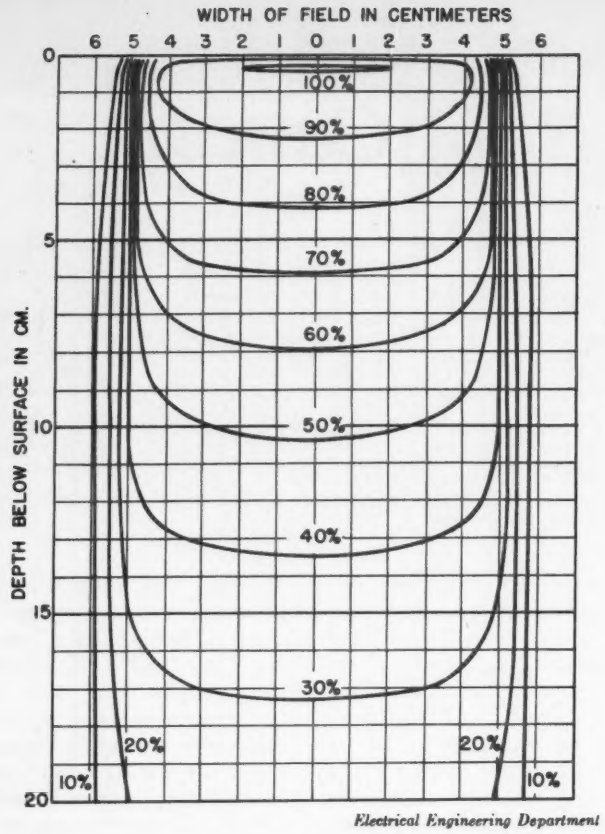
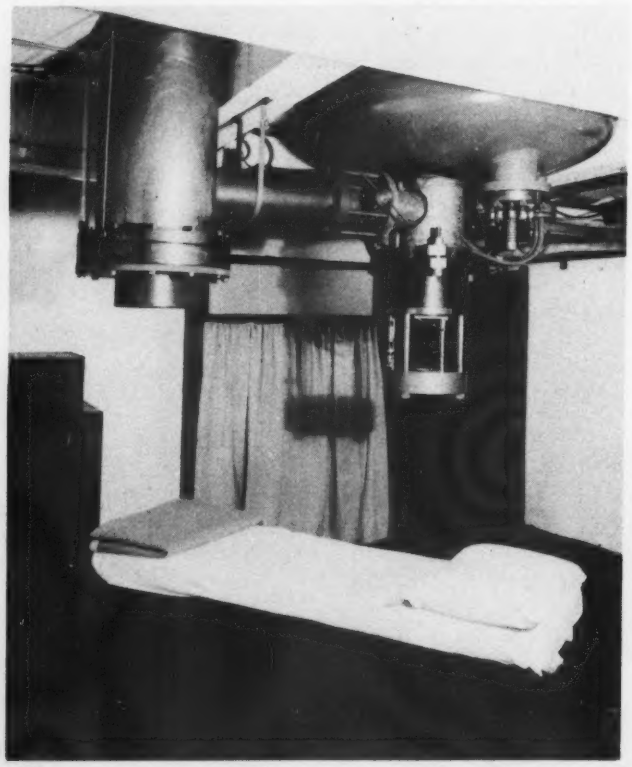


Figure 3. An isodose chart for 2.0-million-volt constant potential x-rays. Treatment distance, 100 cm. with a field of 10 cm. × 10 cm. The filtration is approximately equal to that of 9 mm. lead

Radiation room of the three megavolt x-ray generator. Over 150 complete treatments were given at this experiment station during 1946
Electrical Engineering Department



The radiation of two-million-volt x-rays filtered by a few mm. of lead is nearly equivalent in penetrating power to the gamma rays emitted by radium in equilibrium with its products. Very little radiation corresponding to energies of less than 200 kv. is left unabsorbed by the target and filter system. For comparison, a gamma-ray spectrum of radium is included in figure 1.

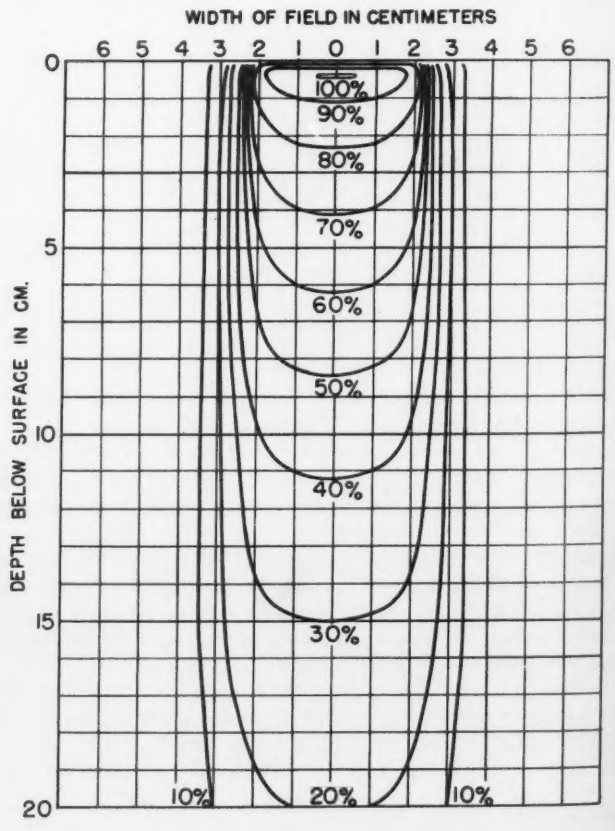
The radiation at the target is not uniform in all directions. Referring to figure 2, we see that for low voltages the intensity is greatest almost perpendicular to the direction of the electron beam; at 500 kv. the intensity maximum is forward at about 40° from the direction of the electron stream; at two million volts, the maximum is directly forward, with the half-intensity points 30° from the maximum; at 20 million volts a narrow beam is formed with about 4½° between maximum and half-intensity points.

At voltages of less than 200 kv., absorption and the spatial distribution just described make necessary the use of reflected transverse radiation, while at a half million volts and higher the forward-directed rays are useful. Because of diminishing beam width, energies of more than 20 million volts are less useful, as no appreciable area can be irradiated uniformly.

With supervoltage radiation, the maximum effect is not at the surface of the body where the x-rays are most intense, but at a depth. At potentials of several million volts, the x-rays incident on tissue-like material are absorbed principally by the Compton process, in which electrons are accelerated. These high-energy electrons accompany the x-rays forward into the tissue, producing many low-energy electrons along their path as they are stopped. These low-energy electrons cause the biological effects. The density of these electrons is greatest at some distance below the surface, where the

(*Continued on page 336*)

Figure 4. An isodose chart similar to that of Figure 3 with the change of the field size to one-quarter of the original area. The field is now 5 cm. × 5 cm. *Electrical Engineering Department*



Gas Turbines

By WILLIAM R. HAWTHORNE
Associate Professor of Mechanical Engineering

Editor's Note: William R. Hawthorne is a graduate of Cambridge University, England, and received his Sc.D. in the Chemical Engineering Department, Massachusetts Institute of Technology. He was development engineer with Babcock & Wilcox Company, England, for three years. At the outbreak of war, Professor Hawthorne joined the Royal Aircraft Establishment and was loaned for a year to Power Jets to do their combustion chamber development and then became head of the Gas Turbine Division of the Royal Aircraft Establishment. Later, after spending one year in the British Air Commission, Washington, D. C., Professor Hawthorne returned to England to become Deputy Director in Charge of Engine Research at the Ministry of Aircraft Production. In 1946 he joined the faculty of the Massachusetts Institute of Technology as an Associate Professor of Mechanical Engineering.

Historical Background

THE idea of the gas turbine power plant must have occurred to many minds at the time when the early steam turbines were being built. But a few simple calculations together with the results of some experiments on compressors and on materials convinced engineers that any such plant would be uneconomical. This conviction was held, with few exceptions, until about 1930, by which time two things had happened to make the gas turbine more practicable. One was a growing development of materials with good mechanical properties at high temperatures. The other was the blossoming and maturing of the new science of aerodynamics which offered techniques by means of which the efficiency of compressors and turbines might be materially improved. Each of these developments assisted the other. Any increase in the efficiency of the components increased the thermodynamic efficiency of the cycle and reduced the temperature required at inlet to the turbine for a certain work output. Any increase in the temperature allowable in the turbine, as a consequence of improvements in materials, increased the specific work output and the cycle efficiency.

There was little doubt about the type of thermodynamic cycle which found most favor. Although Holzwarth in Germany had spent much effort in an attempt to develop a power plant with a constant volume cycle using turbines and turbo-compressors, this was soon dropped. The constant-pressure cycle* with its steady flow offered advantages in simplicity, lack of vibrations, and compactness.

It is these features of simplicity and compactness which first attracted engineers doing research on aircraft propulsion to the gas turbine. Later Frank Whittle added his invention of turbo-jet propulsion with its even greater simplicity and light weight.

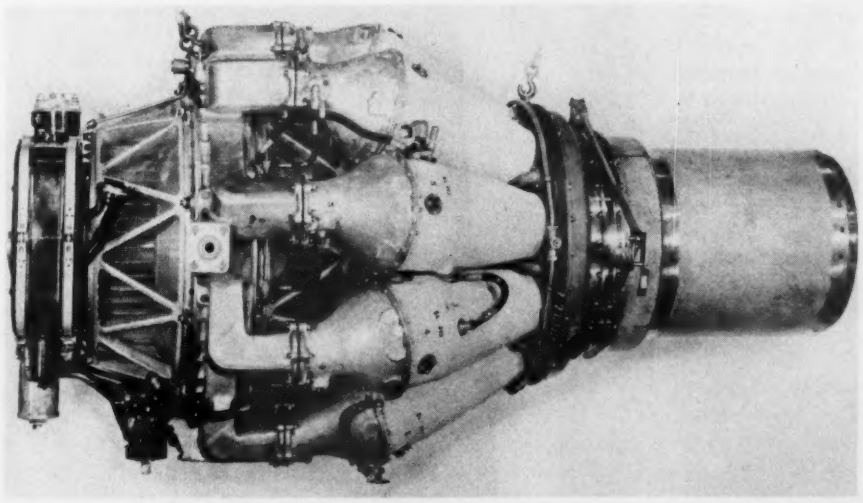


Figure 1. The Rolls-Royce "Derwent"

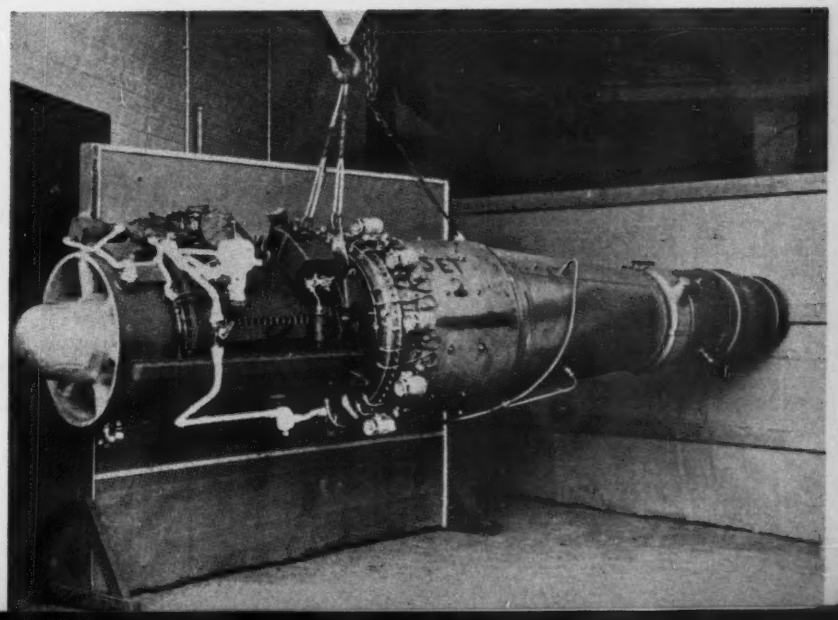
Thornton Laboratories

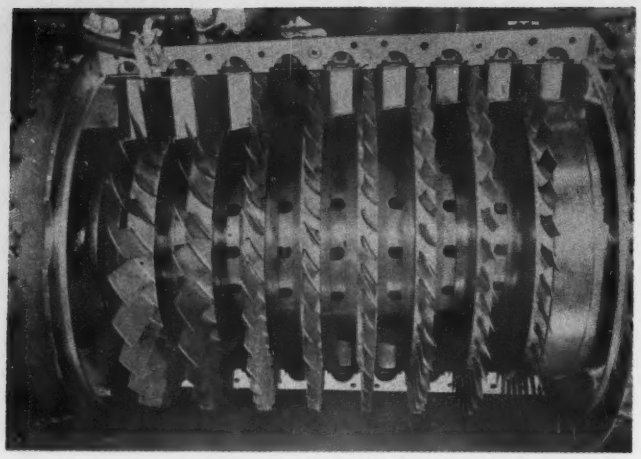
The Brown Boveri Company in Switzerland did most in the early 1930's to convince engineers that the gas turbine was a practical power plant. The compression part of the cycle was the least efficient. Up to this time rotary compressors had efficiencies of the order of 60 per cent, which was far too low for an economical gas turbine. In 1902 Sir Charles Parsons had built a compressor which had fixed and moving blades like a turbine. The performance of this axial compressor was not sufficiently encouraging for further

* In the simplest form of the constant pressure cycle the air is first compressed and then heated. After heating the air is expanded in the turbine which drives the compressor and also provides external power. The flow is steady. Improvements in the thermodynamic performance may be obtained by using heat-exchangers.

Figure 2. An F.2 jet propulsion engine

Institution of Mechanical Engineers, London





Institution of Mechanical Engineers, London

Figure 3. Jumo 004 compressor with disk construction and shrouded stators

development at the time. In the early 1930's, using airfoil theory as the basis of the design, the Brown Boveri Company started building axial compressors for gas turbines. They obtained efficiencies of over 80 per cent at pressure ratios of 4 : 1. This attainment and the use of materials possessing good strength at 1200° F. made the gas turbine a practical power plant.

It is in aircraft propulsion that the gas turbine has made the most spectacular advance. As a turbo-supercharger it was first tried by the British, French, and Americans during 1914–18. Fortunately no very high efficiencies were essential for the compressor and the turbine in the turbo-supercharger; its development depended on the advances in materials and in bearing design. The success of the G. E. turbo-supercharger is primarily the result of dogged perseverance with mechanical and metallurgical problems.

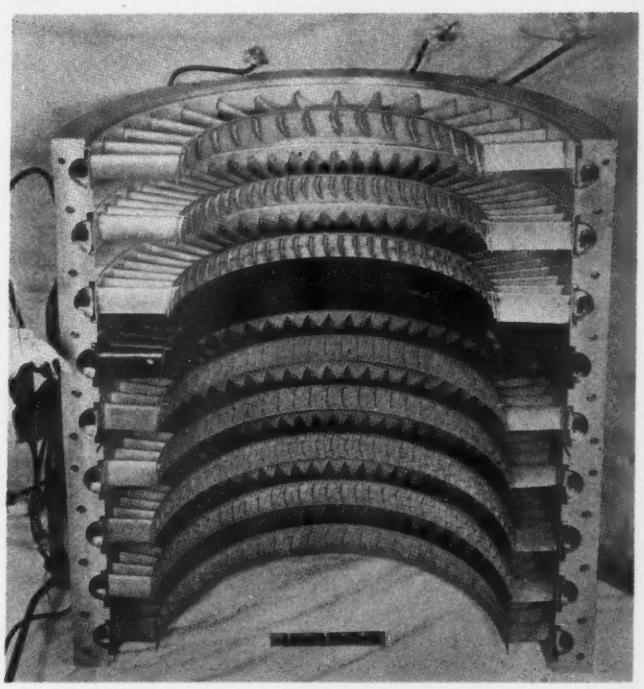
The Turbo-Jet

The first gas turbines to fly were turbo-jets fitted with centrifugal compressors. A diagram of the arrangement of the first British and American engines, figure 11, shows clearly the basic similarity to the turbo-supercharger with the combustion chamber replacing the cylinder and the jet the propeller of the conventional power plant. Simplicity and low weight are striking features of the design. The Derwent V, latest Rolls Royce engine in service, figure 1, develops 6,000 hp. in flight at 600 mph. and weighs just over 1200 lbs. Its compressor has a pressure ratio of 4 : 1 at sea level and an efficiency over 75 per cent. Normally jet engines are not rated in horsepower but in thrust, which varies little with forward speed. On this basis the engine weighs about 0.3 lb. per pound thrust and consumes, on the test bed at sea level, just over one pound of fuel per hour per pound of thrust.

Axial vs. *Centrifugal Compressor*

The axial compressor seems to offer some 10 per cent more efficiency than the centrifugal. It has about one-third the frontal area for the same air flow as the centrifugal, but it is longer and more expensive to make. These differences may be seen by comparing figure 1 with figure 2, which shows an early turbo-jet with an axial compressor manufactured by Messrs. Metropolitan-Vickers Ltd.

The views of the German Jumo 004 compressor, figures 3 and 4, show the similarity between the axial

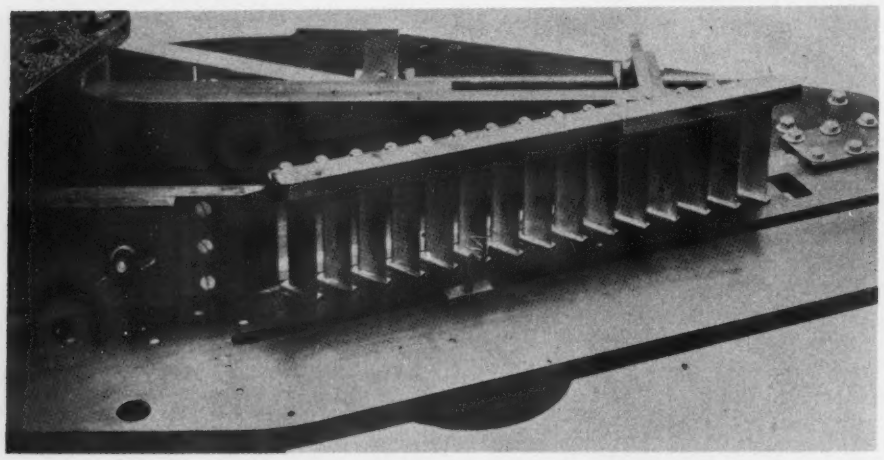


Institution of Mechanical Engineers, London

Figure 4. View of stator and blades for Jumo 004 compressor

compressor and the turbine. In the turbine air is deflected and expanded; in the compressor it is deflected and diffused. Because it is difficult to turn air round a corner and reduce its velocity at the same time without incurring losses, the air turning angles in the compressor may not be more than 30°, whereas in a turbine they are of the order of 100° and more. This means that the pressure rise per stage of moving and fixed compressor blades is very much less than the pressure drop in a turbine stage. Consequently, the compressor always has more stages than the turbine.

Figure 5. A high-speed cascade tunnel Institution of Mechanical Engineers, London



Aerodynamic Research

Just as wings are developed in a wind tunnel, so compressor and turbine blades are studied in the cascade tunnel, figure 5. Here the effect of different airfoil shapes, spacing, setting angles, and Rey-

nolds and Mach numbers on the turning angles and losses are determined. Many such tests have been done in the past on steam turbine blades. The cascade test results show that the use of blades shaped more like airfoils might be profitable in gas and steam turbines as well as in compressors. This requirement conflicts with another, namely that the blades should be thickened to stand the centrifugal and torque loads.

The Combustion Problem

It is now well known that the combustion of the fuel and subsequent production of a uniformly heated stream of gas is a major problem in the aircraft power plant. In many engines, combustion occurs in a number of pipes arranged symmetrically about the rotor axis, figure 1. In others, figure 2, the combustion chamber is the annular duct between the compressor discharge and the entry to the turbine nozzles.

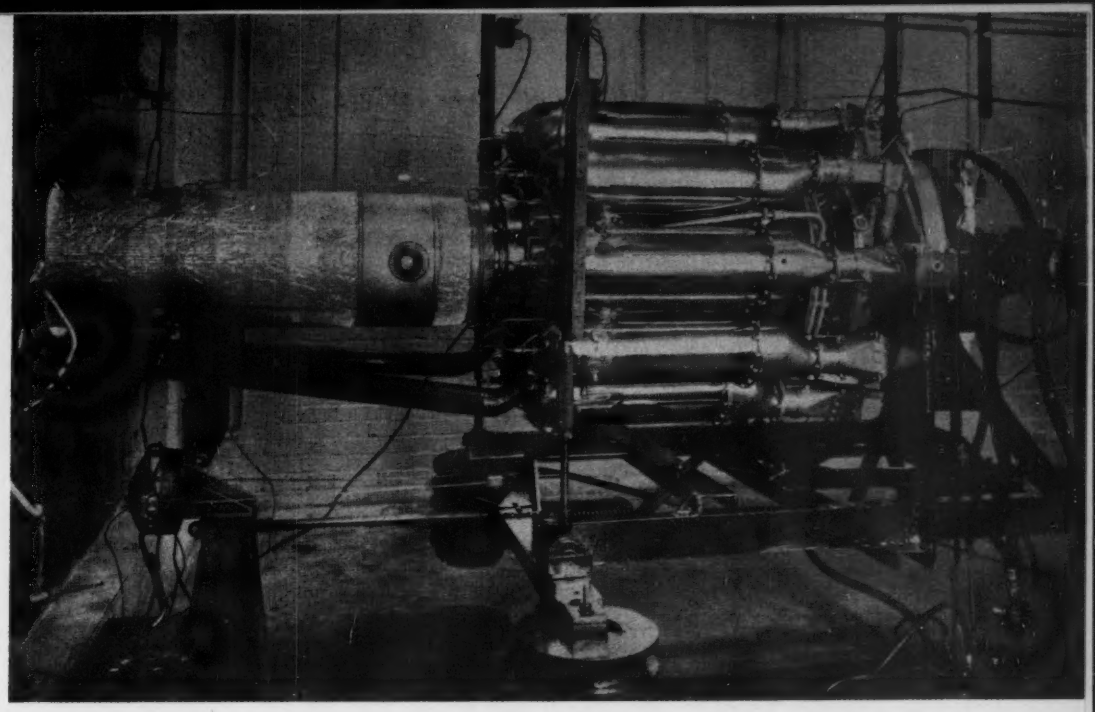


Figure 6. Engine arranged on the test bed for the acceptance test M-26

Institution of Mechanical Engineers, London

One of the problems in the combustion process may be likened to that of keeping a match alight in a 60 mph. wind. The high velocity arises because of the need for keeping the dimensions of the combustion chamber small. Just as the pipe smoker solves this problem by cupping his hands to form a stagnant region in which his match can burn, so baffles are arranged to form an eddying wake into which fuel is injected. To achieve rapid combustion the liquid fuel is sprayed in fine droplets into just enough air to burn it completely. Rapidly turbulent mixing of the remainder of the air with the flame is then required in order to reduce the temperature to a uniform value low enough for the turbine blade materials to withstand. This mixing must not be so rapid that it chills the flame or so slow that the flame becomes smoky and long.

Another problem is that the velocity of the air entering the combustion chamber is unlikely to be uniform. Any asymmetry will cause local overheating of the thin sheets forming the walls. These and many other troubles have to be overcome by hours of patient trial and error on the test rig.

Figure 7. Failure of turbine blade, 0.8 inch chordal width: side view

Institution of Mechanical Engineers, London

Figure 8. Failure of turbine blade: end view showing fracture

Institution of Mechanical Engineers, London

Matching of the Components

In developing a gas turbine, it is desirable to test all the components separately before assembling them into a complete engine. This practice shows up any mis-matching between the turbine and compressor. Often it is not possible to find enough air or power to do this,* and the engine has to be run without previous testing of the components. Then serious difficulties may arise if the turbine is not the right size for the compressor. If the turbine is too small, high temperatures are required to enable it to drive the compressor, or the velocities in the compressor may be reduced to the point where the blades stall and the flow either pulsates or the efficiency decreases so much that the engine cannot be run. If the turbine is too large, the temperature decreases appreciably below the design value and the output of the work or thrust is reduced.

Engine Testing

Once the components are assembled in the form of an engine the

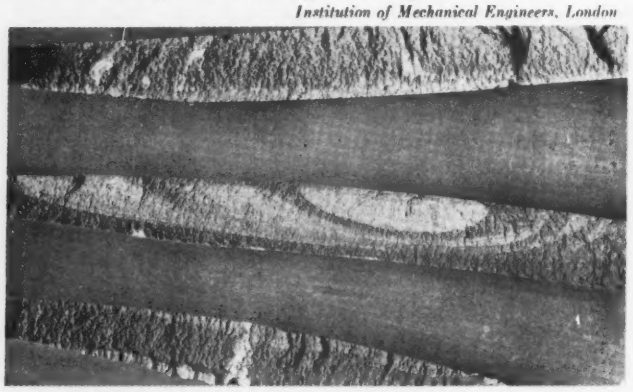
* Air consumption of gas turbines is measured in pounds per second. A turbojet of 4,000 lbs. thrust consumes just over 80 lbs. of air per second. Powers are measured in thousands of horsepower. Quite a small jet engine may need 5,000 hp. to drive its compressor.

final stage in the development of the engine starts. This is a most important stage in the development of an aircraft engine, for it is on the test bed and in flight test that the design is matured. Some ten to twenty thousand hours, or more, of test running are generally required for this process, involving perhaps fifty or one hundred engines of the same basic design, before the "type" can be released for service. Even then modification and development is not completed but continues throughout the useful life of the engine.

The test bed for a turbo-jet engine is comparatively simple, figure 6. The engine is mounted in a cradle suspended by four rods from the roof. The thrust is measured by a spring balance or hydraulic piston incorporated in the connection between the freely swinging cradle and a post fixed to the floor (shown on the left in figure 6). Accurate measurement of fuel flow and gas pressures and temperatures at key points in the engine are required. Measurement of airflow is desirable and. may for instance, be achieved by hermetically sealing the engine test cell except for a calibrated orifice, through which air may enter. and an aperture for the discharge of the jet.

Figure 10. The appearance of fatigue fracture at the root of the vane of the impeller

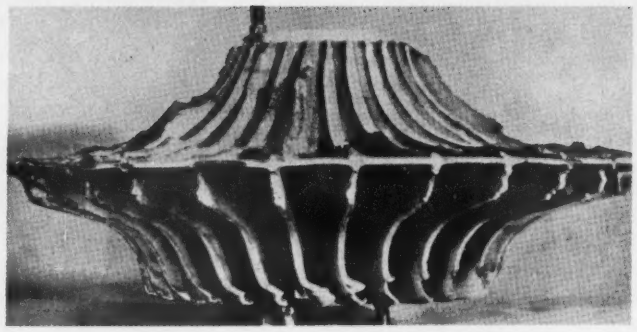
Institution of Mechanical Engineers, London



Engineers, seeing a turbo-jet on test for the first time, are often amazed by the lack of vibration. This is so small that it was at first necessary to attach a mechanical vibrator to the instrument panels of jet aircraft in order to overcome the slight friction present in some instruments. When flying in a turbo-jet aircraft there is comparatively little noise so that it is possible to hear the engines of a neighboring aircraft. Other attractive features are the simplicity of the control system, ease of starting, the almost negligibly small consumption of lubricating oil and the absence of any special cooling air supply or radiator.

Mechanical Problems

While some of the engine testing time is devoted to measuring the performance of the engine and the effect of modifications on the performance, the major portion of the time is devoted to finding and overcoming mechanical weaknesses which may limit the performance or its further improvement. Mechanical problems of the gas turbine arise due to creep at high temperatures, thermal distortion, bearing development, and lubrication, seals, controls and to fatigue due to the fluctuating aerodynamic loads on vanes and blades. Those peculiar to the gas turbine are creep, distortion due to differential



Institution of Mechanical Engineers, London

Figure 9. Impeller wrecked through fatigue failure during tests

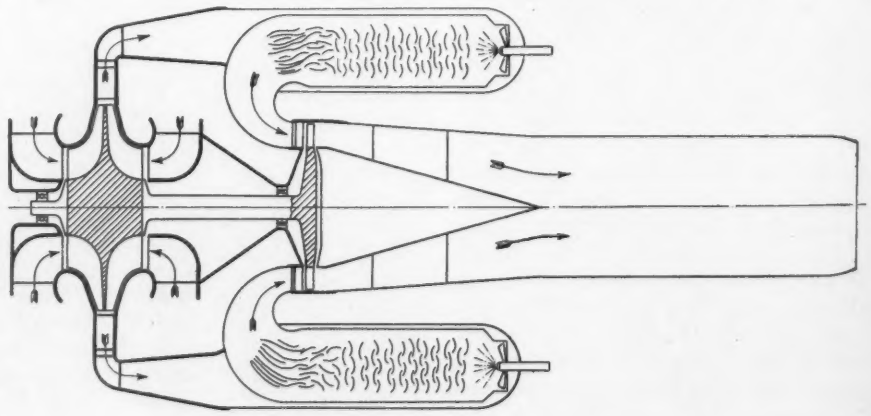
thermal expansion and fatigue. For the short life required for an aircraft engine, creep problems can be overcome by comparing calculated stresses with creep strengths and by cooling at critical points, such as the rim of turbine discs. The fatigue problems are more serious. If the designer has made every effort to reduce weight, the aerodynamic loads on vanes and blades will be high. Because each rotor vane or blade is required to pass through the wake or disturbance caused by a stationary nozzle or vane, the loads are not steady but fluctuate in a manner which is difficult to predict. Should the frequency of passage of the blade through these disturbances coincide with one of the natural frequencies of vibration of the blades, the magnitude of the fluctuating stress may rise to an intolerable value and failure of fatigue may occur, figures 7–10. The existence of this possibility has long been known to steam turbine designers who have used shrouds and lacing wires to hold the blades at various points along their length and thus dampen out vibrations. Aircraft gas turbine designers prefer not to use such devices because they interfere with the air flow and, in the case of shrouds, add weight at the tip of the blades, thereby increasing the centrifugal stresses. Both of the failures shown in figures 7 and 10 occurred because of resonance between the fluctuating aerodynamic loads and the natural frequency of the vane. The cure is to alter the natural frequency of the vane, generally by thickening it, so that it could not be in resonance with any of the major fluctuations in the aerodynamic forces.

Turbine Propeller Engines

The advantages of the gas turbine for propeller drive are that it considerably reduces the fuel consumption required in a given flight compared to that for the

(*Continued on page 348*)

Figure 11. A simple centrifugal jet unit *Institution of Mechanical Engineers, London*

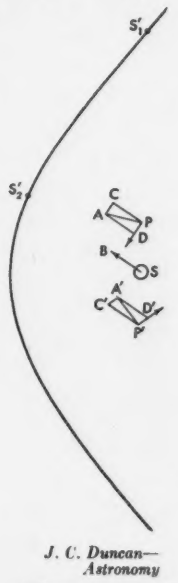


THE BIRTH OF THE PLANETS

By PETER B. NEIMAN, '49

ONE of the most fascinating branches of astronomy is that dealing with the evolution of celestial bodies. It is the science which tries to calculate the evolution of nebulae into stars, and of stars into planetary systems. The evolution of nebulae into stars has already been discussed,[1] and we shall turn now to the evolution of the Solar System.

Astronomers feel certain that the present Solar System is the result of a definite evolutionary process, since it displays a number of characteristics which are too neat and orderly to be the workings of chance. However, there is no one theory of how the Solar System arrived at its present state that is accepted by all astronomers. There probably will never be one, because of the highly speculative nature of a theory dealing with what happened 10_n years ago, where n is any large number. There are, however, three theories that can fairly accurately explain such phenomena as the fact that all the planets lie in nearly the same plane, that they all revolve around the sun in the same direction and that all the orbits are nearly circular ellipses.



J. C. Duncan—Astronomy

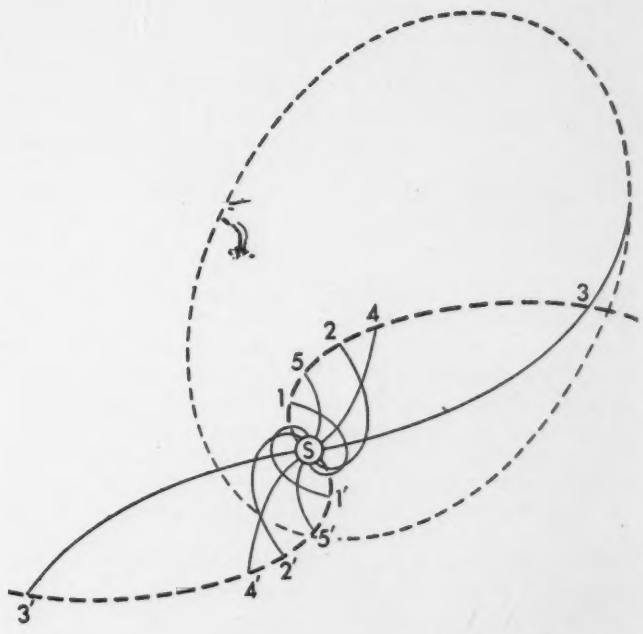
Figure 1
Tidal effects of an encounter of two stars

The first of these theories is the Laplace Nebular Hypothesis. It is based upon the assumption that the sun was once a highly diffuse body. which had a radius extending at least to Pluto, the farthest of the planets. By mutual gravitation, this nebulous mass began to contract. If it had an initial rotary motion, it would have had to spin faster as it contracted, in order to conserve angular momentum. There would come a time when the outer edge would spin fast enough to counteract gravity, and would thus be left spinning in space, while the inner material went on contracting. As the sun shrunk, it would then leave a number of rings of matter in space. After a while, the gravitational attraction of the various segments would pull all the parts of it together in the form of a spheroid, revolving in the path of the ring, the so-called planetary orbit.

The theory does explain most of the observed facts about the Solar System, but there is one serious drawback. That is that the measured angular momentum of the Solar System, and the calculated momentum for such a system when it had a radius greater than the distance from the sun to Pluto, do not agree. Since the theory assumes that little or no mass has left the system since its beginning, the discrepancy in angular momenta is a challenge to its validity.

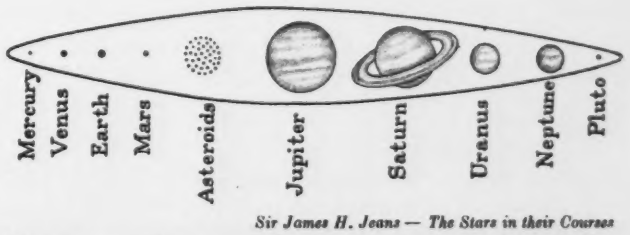
The second theory is the Planetesimal Hypothesis. It postulates the close approach of another star with the sun, rounding the sun in an essentially hyperbolic orbit, so that the time lapse while it passed the perihelion point, or point of closest approach was of comparatively short duration. To visualize what would happen, refer to figure 1. Let S_1' be an early position of the foreign star S' on its hyperbolic relative orbit, and let P and P' be two particles ejected from S in directions toward and away from S'. These particles have departed almost radially from S, and if left to themselves would fall directly back. But S' continues swiftly in its orbit and soon occupies the position S_2'. Its attraction upon P and P' will then be in the directions PA and $P'A'$ respectively, and its effect upon the motion of these particles relative to S may be determined. Thus draw PC and $P'C'$ equal and parallel to SB, the acceleration produced by S' in S. Complete the parallelograms $PCAD$ and $P'C'A'D'$ upon the diagonals PA and $P'A'$, taken of such length as to represent

(*Continued on page 356*)



J. C. Duncan — Astronomy

Figure 2. Formation of a spiral according to Chamberlin and Moulton



Sir James H. Jeans — The Stars in their Courses

Figure 3. The sun and planets drawn to scale

The planets are arranged in order from the sun, and we see how their size increases until Jupiter is reached and then diminishes again. Only the sizes, not the distances, are drawn to scale. If the distances were to scale the earth would be 11 yards, and Pluto a quarter of a mile, away from the sun.

[1] See *T. E. N.*, May, 1946.

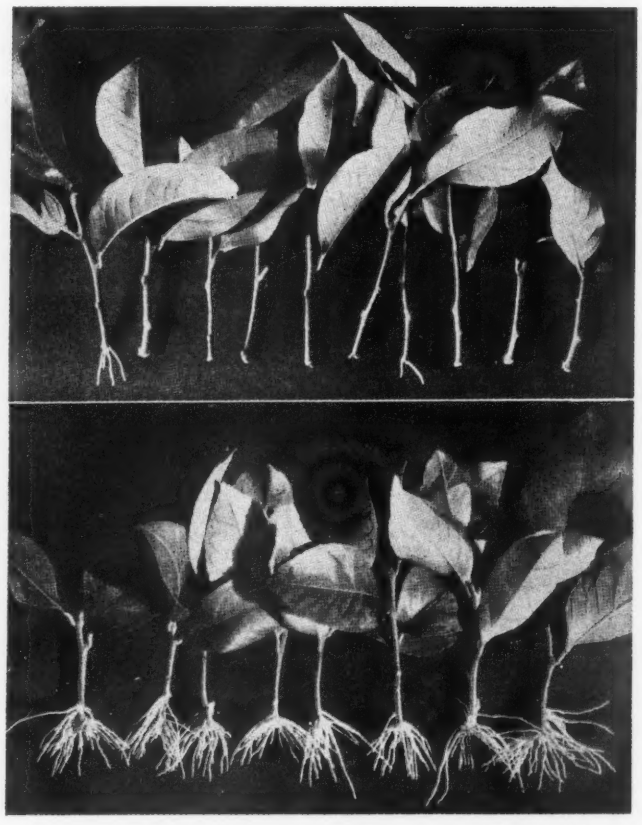
Phytohormones

By HARRISON C. WHITE, '50

PARTHENOCARPIC fruit — seedless tomatoes, and even seedless watermelon — is now being produced by treatment with plant hormones in the laboratory, and perhaps will soon be available commercially. The number of other applications of plant hormones, which will be discussed at the end of this article, is large and growing. Have all these applications been discovered by chance? No: they have been worked out as a result of fundamental, planned research on plant growth. Not only does this research have much practical application, but it is fascinating in its own right, for what could be more interesting than the study of growth, and hence life?

Before we go on to a detailed consideration of plant hormones or, if you please, phytohormones, it would be well to define the term "hormone" precisely. An authority in the field gives the following definition: "A hormone is a substance, or chemical messenger, which, transported through the body, determines the growth or function of parts remote from its origin." A characteristic of almost all hormones is that they act in minute, sometimes very minute quantities. Of course, external growth factors are very important in determining the growth of a plant, but we shall assume that such external factors are held constant so that we can study the effects of internal factors alone.

Even a few centuries ago men like Agricola had vague conceptions of substances moving through the plant, regulating growth. In 1758 Duhamel du Monceau performed numerous experiments which led him to believe that there was a definite stream of growth promoting substances moving through the plant, regulating growth. In the late nineteenth century Sachs experimentally developed a concept of special organ-forming substances which were polarly distributed. Soon tropisms, the movements of plants under external stimuli, came to be regarded as growth phenomena brought about under hormonal influence. During the last half century hundreds upon hundreds of papers have been published upon different facets of this huge subject.

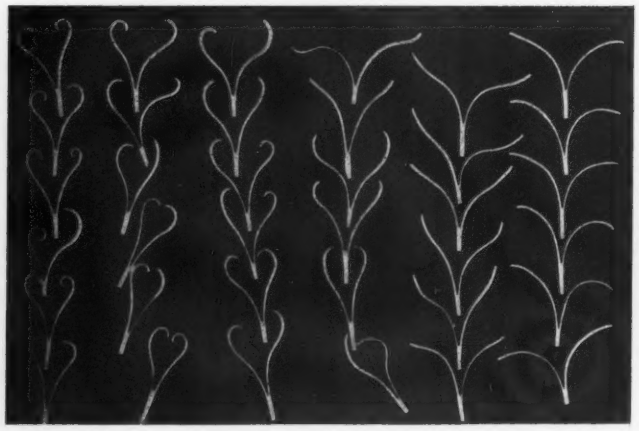


Plant Physiology

Rooting of lemon cuttings. Upper row, eight hours in tap water; lower row, eight hours in indole-3-acetic acid (highest non-toxic concentration, 500 mg. per liter). Photographed seventeen days after treatment

Curvature of split stems of etiolated pea seedlings in auxin solutions. Concentrations, left to right: 6.45, 2.15, 0.645, 0.215, 0.0645 and 0 mg. of indole-3-acetic acid per liter. Photographed after twelve hours in solutions

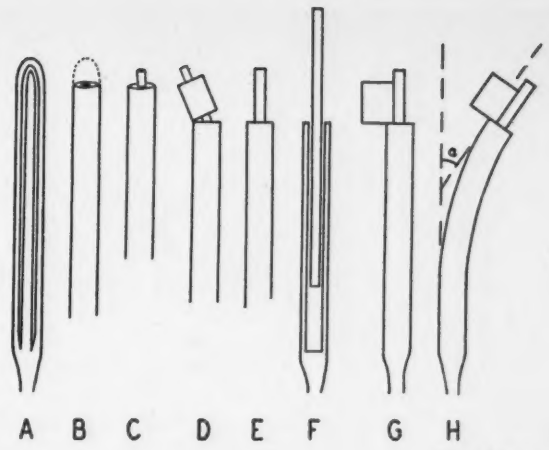
Macmillan Company



The classic plant in the study of plant hormones has been the *Avena* (oat) coleoptile ever since Charles Darwin made the first serious study of plant growth using it. The *Avena* coleoptile is the young shoot of the oat plant. It consists of a seed leaf, a root system, and a cylindrical, hollow stem with a solid tip, the coleoptile, in which is enclosed the developing primary leaf of the plant. The basic experiment is carried out as follows: The tip of the coleoptile is cut off; growth slows down in it, while a control coloeptile continues to grow at the normal rate. The tip of the decapitated coleoptile is placed on an agar block for several hours. The agar block is then put on the decapitated coleoptile, which promptly resumes normal growth, while a control decapitated coleoptile which has had a pure agar block placed on it grows very little. Therefore growth must be caused by a diffusible substance emanating from the tip of the coleoptile. A refinement of this experiment consists of placing the agar block containing the growth substance on one side of the coleoptile only, usually pulling loose the primary leaf and leaving it projecting as a brace; the side under the agar

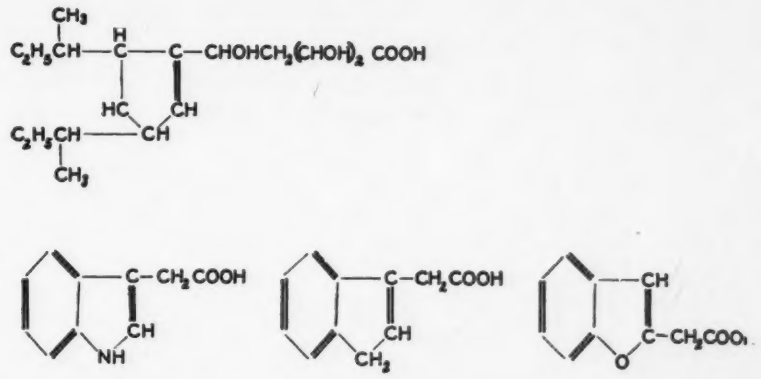
gets practically all the growth substance and hence grows normally while the other side scarcely grows at all; in this way the coleoptile curves toward the side which has no growth promoting substance. Of course, for the sake of accuracy, the coleoptiles must be grown under constant conditions and used always at the same age. The other two principal tests for growth-promoting substances are the split pea test, in which the degree of curvature of split pea stems grown in solution containing growth substances is measured, and the straight growth test, in which the straight growth of very short sections of coleoptile mounted on the teeth of a comb placed in solution containing a growth substance, are measured under the microscope.

So far we have been talking glibly of "growth substance." We now seem justified in calling this "growth substance" a plant hormone, for it satisfies our definition. Let us furthermore call this plant hormone which comes from the coleoptile tips an "auxin." We have so far shown auxin to exist only in one plant, the oat seedling. Does it occur anywhere else? Yes: investigation has shown that there is present in all the higher plants which have been studied a substance which is an auxin because it produces growth in the oat seedling and has all the other properties of auxin. Furthermore it has been shown that many animal secretions, particularly human urine, are a very rich source of auxin. We have seen that auxin is present in probably all higher plants; where is it located in the plant itself? Investigation has revealed that in older growing plants auxin is formed in the growing tips or buds, and also in young leaves, its concentration decreasing with increasing distance from the tip. In the very young plant, however, auxin has been shown to be present in an inactive or precursor state in the seed, whence it moves up to the growing tip where



Macmillan Company

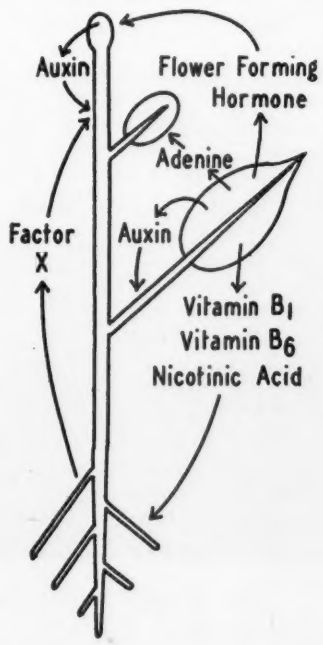
Diagrammatic summary of procedure in an Avena test. A, intact; B and C, decapitated; D and E, decapitated for the second time (primary leaf protruding); F, primary leaf pulled loose; G, application of the agar block containing auxin; H, showing the resultant curvature



Plant Physiology

Above, auxentriolic acid (auxin a) according to Kögl, Haagensmit, and Erxleben. Below, left to right, its resemblance to various compounds is indicated by a comparison with indole-3-acetic acid, indene-3-acetic acid, benzofuran-2-acetic acid

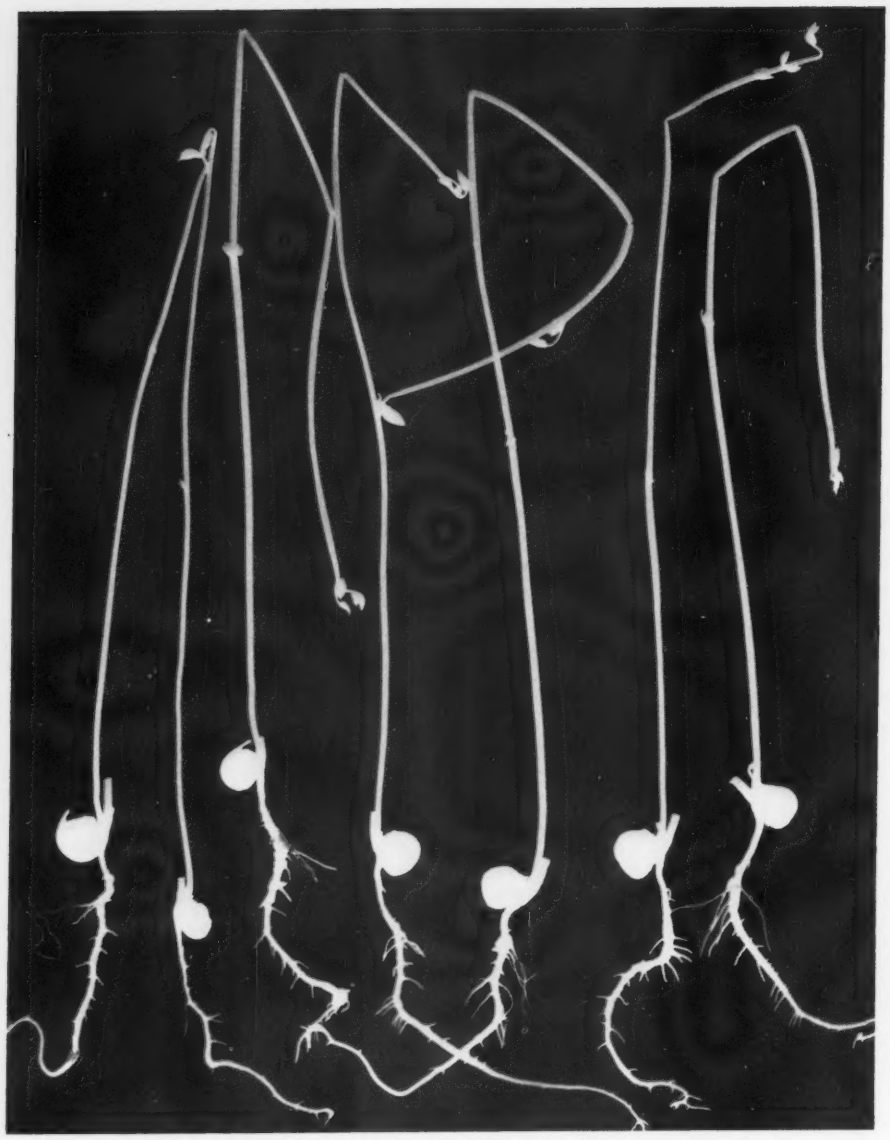
An illustration of the relationships of the organs of a plant. Arrows indicate in which organ a specific substance is produced and the region to which it is translocated in order to perform its function. The sugars coming from the mature leaf are not shown. In downward sequence are indicated: apical bud, growing stem, growing leaf, mature stem, mature leaf, and root system



American Scientist

it is activated, this process continuing until the young plant is able to synthesize its own auxin. One very important fact to remember about auxin is that only a small fraction of it is in the active, free-moving state in which it diffuses into agar; instead most of the auxin in tissues is in the "bound" form. It seems probable that the growth of the plant is controlled not by the actual rate of auxin production, but by the rate of conversion into the active form. This hypothesis would make it much more easy to explain why plants start to grow at a furious rate in the early spring, and then abruptly stop at the beginning of summer when one would think the external conditions were just right for the production of both auxin and structural materials; it would also help to explain the formation of large nodules and galls on plants by certain types of fungi; *i.e.*, the fungi would convert all the inactive auxin over to the active form.

We have seen that there actually is such a thing as a growth hormone; can we isolate it and discover its chemical properties? Even at the beginning, the pioneer workers were able to tell a number of things about auxin: from its diffusion rate, a molecular weight of



The terminal bud of the seedlings shown above has been removed, permitting considerable growth of the lateral bud

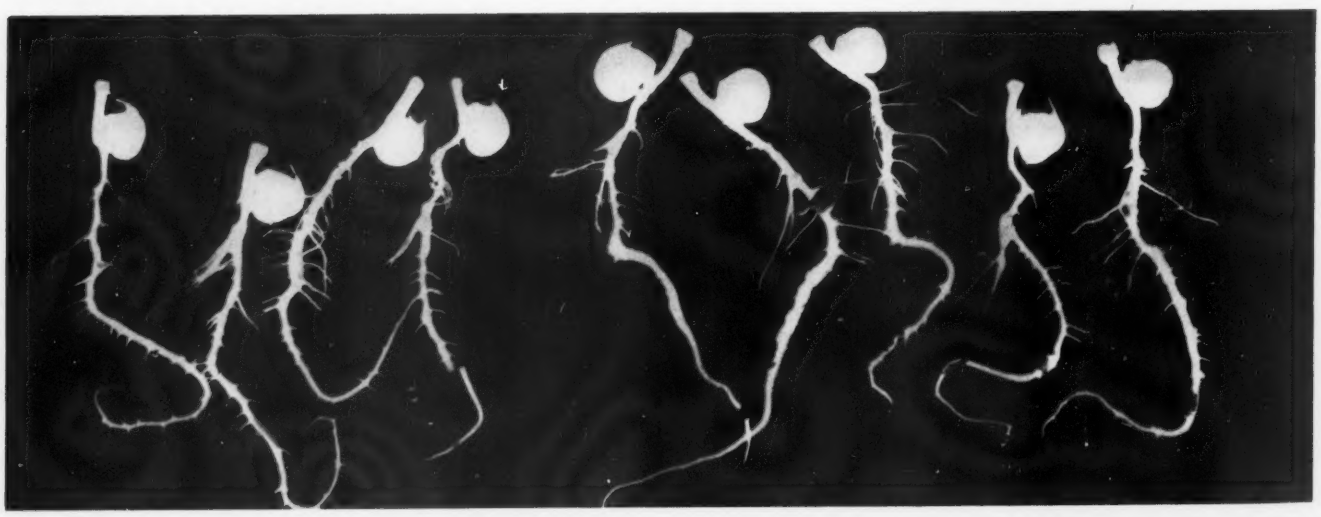
In this set of seedlings, auxin paste has been applied to the stump left by the terminal bud, greatly inhibiting the growth of the lateral bud

between 300 and 400 was estimated, and it was also determined that auxin was heat and light stable. These observations were later confirmed when two biochemists, Haagen-Smit and Kögl, isolated pure auxin. At first the two workers tried to isolate the substance diffusing from the coleoptile but gave it up as too slow a process. Then they discovered that human urine was a rich source of auxin and succeeded in working up a few hundred milligrams of pure substance which they called auxin "a." In order to confirm their work they also isolated auxin from germinating barley and from corn-germ oil in the form of both auxin "a" (auxentriolic acid) and auxin "b" (auxenolonic acid). The empirical formula of auxin "a" is $C_{18}H_{32}O_5$ and of auxin "b" $C_{18}H_{30}O_4$. Their structure was shown to be (see next page):

Auxin "a"

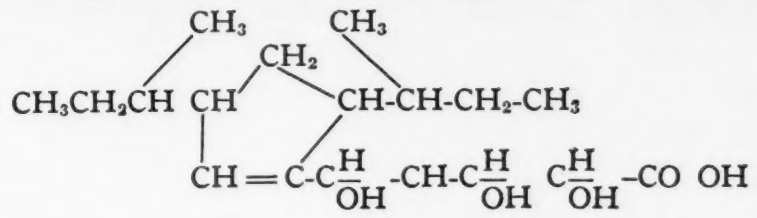
Auxin "b"

Kögl and Haagen-Smit furthermore discovered that a much more common substance, indole-3-acetic acid, had the same effect on plant growth as auxin. Since that time quite a large number of substances have been shown to have growth promoting activity: among the chief ones are a great many of the derivatives of indole acetic acid, and a large number of other unsaturated ring-containing acids such as the acetic derivatives of indene, naphthalene, anthracene, thiophene. The esters and amides of these substances also have some activity, probably because they are hydrolyzed in the plant into the corresponding acids, which alone seem to be the actual hormones. Indeneacetic acid is of theoretical importance because it is not readily transported through the plant like the other auxins, although it is locally active. Dichloro-phenoxyacetic acid and α-Naphthaleneacetic acid are stable and cheap

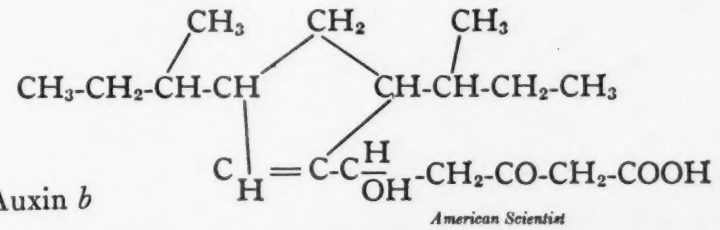


enough to be of use commercially in horticulture. Originally it was thought that auxin "a" and auxin "b" were the only naturally occurring auxins, but now it seems that indole-3-acetic acid is the most common auxin, since it has been actually isolated from maize and shown to be present in a number of other higher plants. It is readily seen why this should be so when you realize that indole-3-acetic acid is very closely related to tryptophane, a normal amino acid which plants must produce anyway for proteins.

The transport of auxins is of primary importance and therefore has been much studied. It was found that, contrary to what one might expect, the auxins are transported through the whole parenchyma and not just the vascular bundles. One of the most interesting properties of auxin transport is its strict polarity: active auxin moves only from apex to base unless very high, unphysiological concentrations are present. This polarity is not just due to gravity; for instance weeping willow twigs, which are always inverted, still are strictly polar as regards auxin transport. Then again, if a



Auxin *a*



Auxin *b*

American Scientist

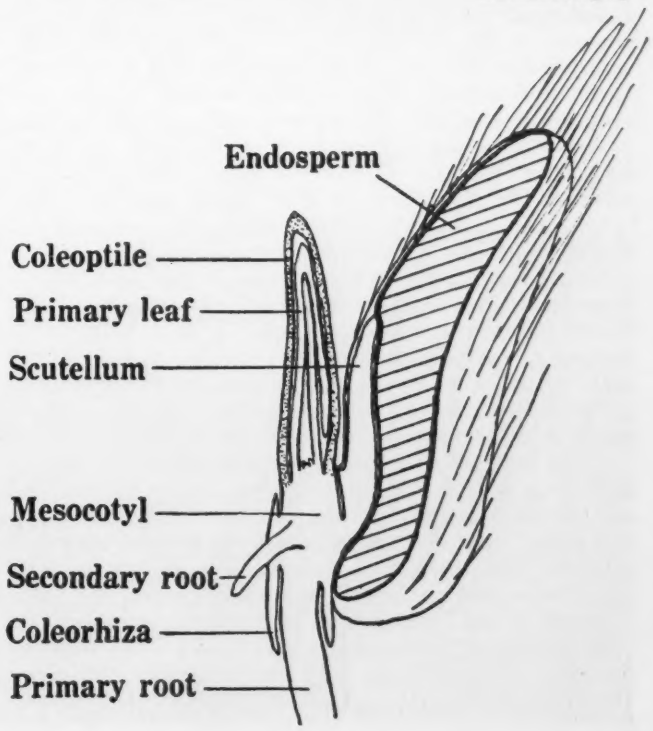
section of a coleoptile is cut out, and another section put in the place of the first, auxin will not move across the inserted section if it has been inverted. How is this polarity brought about? No one knows. There are a number of theories concerning the mechanism of the action, none very satisfactory. Some investigators have tried to tie up the movement of auxin with the streaming of cell protoplasm, and in this way it is possible to account for the relatively high velocity of auxin transport, about 15 mm/hour — several times that possible by diffusion alone. However, neither this hypothesis nor the one which assumes that auxin moves between the faces of the cell walls at the high velocity associated with such movement explains the polarity of auxin transport. Since it was known that acid organic dyes moved primarily toward the roots, which are slightly positive electrically with respect to the stem, for a long time it was believed that the polarity might be of an electrical nature. However, it has since been shown that it is possible to destroy the electrical polarity of the coleoptile without eliminating auxin transport polarity and *vice versa*. Hence, we are for the present left without any adequate explanation of the fundamental and important phenomenon of auxin transport polarity.

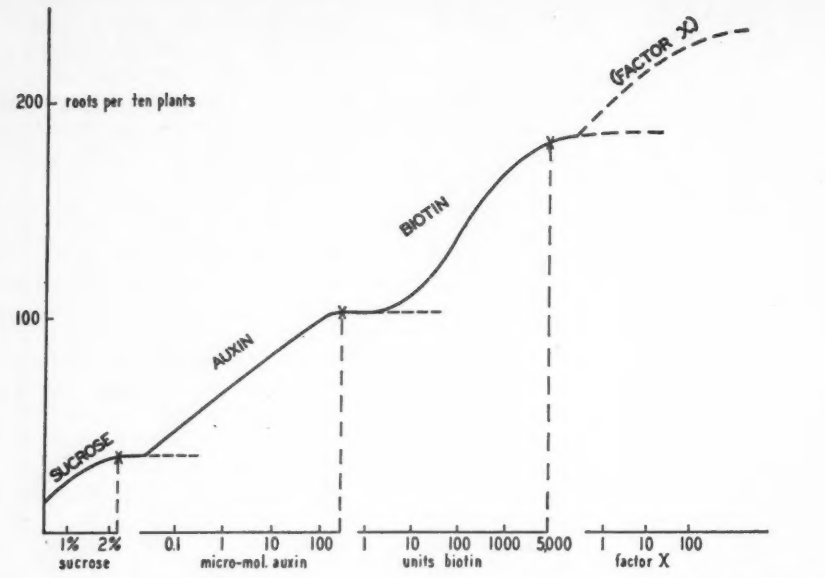
Tropisms, the movement of plants under external stimuli, have been perhaps at least as well explained by the auxin theory of plant growth as any other set of phenomena. Geotropism, the movement of plants under the influence of gravity, is one which all of us have encountered. The basic phenomenon is that when a young, growing plant is placed in a horizontal position, the stem bends and grows upright again. This phenomenon is quite plausibly explained if we assume that gravity causes more auxin to be concentrated in the lower side than the upper. That more auxin is actually concentrated in the lower side than the upper side of a horizontal stem was demonstrated in two independent investigations which showed that 62.5 per cent of the diffusing auxin came out of the lower half of a horizontal stem and 37.5 per cent out of the upper half. The lower half will obviously grow more than the upper half, this situation producing a curvature which continues until the stem tip is vertical again. One other possible explanation of geotropism was brought forth when it was discovered that the pH of the lower half of a horizontal stem was 0.1 unit more acid than the pH of the upper half; hence it might be assumed that more free auxin would be present in the acid half. This latter suggestion is now considered unlikely, though, for a number of reasons. Since the relative concentrations of auxin in horizontal stems is the same in different types of plants, it is assumed that there is one basic mechanism which brings about this geotropic distribution. The best theory of the nature of this mechanism rests on the observed fact that across horizontally placed plant organs there develops a potential difference of five to ten millivolts, the upper side always being negative with respect to the lower side. This potential might tend to concentrate auxin in the lower side, although it has never been proved conclusively that auxin is affected by electrical potentials in the plant.

Phototropism is the other principal type of tropism. The funda-

A longitudinal section through Avena *seedling after thirty hours' germination, at the beginning of the period of rapid elongation*

Macmillan Company





Macmillan Company

Interaction of factors causing root formation in Pisum *cuttings. Ordinate, roots per ten plants; abscissa, concentration (log. scale) of the factor which is limiting root formation*

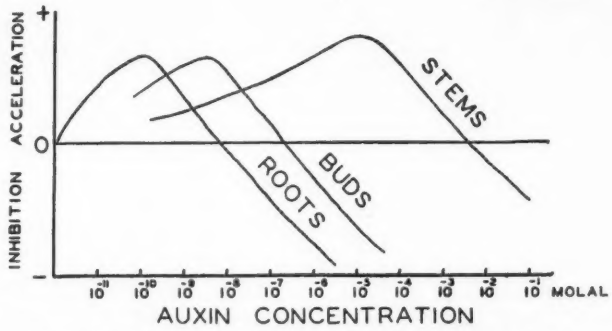
mental phenomena involved are the bending of a plant toward light, and the bending of leaves from shade into light. Phototropic responses are much more complicated to study than geotropic responses; for one thing the amount and even the sign of the phototropic curvature varies in at least two cycles with changing light intensity, the maximum curvatures occurring at 200, 20,000 and above 100,000 meter-candle seconds. Furthermore, the unilateral illumination need be applied for only a short time in the case of phototropism for there to be noticeable effects, and these effects continue for up to six hours after exposure, while in geotropism the plant is back to normal in forty minutes, and must be exposed for one half hour before effects develop. Experimental measurements have shown that the excess of auxin on the dark side over that on the light side increases as the curvature toward the light increases; hence we can deduce that auxin distribution determines phototropic effects. The question is: how is this differential developed? The answer seems to be that the difference in auxin concentration on the light and dark sides is a resultant of three effects: unilateral light polarizes the plant cells so that auxin flows from the light to the dark side; some auxin is detroyed by light on the light side; and, after several hours, the rate of auxin production on the lighted side is increased, which phenomenon accounts for the puzzling tendency of the curved stem to straighten out after several hours. The turning of leaves into the light is due to differential auxin distribution in the leaf petiole due to differences in the illumination of different parts of the leaf, which result in different rates of auxin production.

Now we turn to root growth phenomena, where we shall meet different hormones. For a long time it was not known definitely whether or not auxin promoted root growth; for there were conflicting reports upon the subject. The truth has now been found to be that auxin helps root growth when present in very low concentrations and hinders it at higher concentrations. In addition, the same thing has been found to be true for the effect of auxin on stem growth and bud inhibition. The reason behind these phenomena is not as yet known. One singular fact about the effect of auxin on root growth is the fantastically low concentrations of auxin which have effects upon roots. A biologist calculated that in order to dilute one gram of indole-3-acetic acid so that it would have no effect on *Zea* roots one would need about 12×10^7 tons of water! Another unusual phenomenon is that auxin often has a delayed effect in producing root growth.

If auxin does not control the growth of roots to any great extent, what hormones do? The answer is that there are three hormones principally responsible for the control of root growth: vitamin B_1, vitamin B_6, and nicotinic acid. However, we cannot grow roots in a medium containing only vitamins B_1, B_6 and nicotine acid, for there must be nutrients present; it becomes more and more clear the more we learn about plants that all the factors involved in growth are hopelessly interwoven. One plant might have an excess of vitamins but a deficiency of sugar; so sugar would be the *limiting factor* which would seem to cause growth. In another plant the situation might be entirely different. However, in cases where the external conditions are suitable and sufficient nutrients are available, vitamin B_1 and B_6 plus nicotinic acid seem to be the factors controlling growth, even though they are present in very small quantities.

Scheme for the approximate ranges of growth acceleration for different plant organs

Plant Physiology



Seemingly closely related to root growth is root formation. Here, however, concentrations of auxin which would be detrimental to root growth are necessary for root formation. In root formation we have an excellent example of a complex system of factors affecting growth. Although it was soon proved that auxin was necessary for root formation, it also soon became evident that a number of other factors were involved. Roots would not appear on cuttings of etiolated seedlings in an auxin solution unless carbohydrates were added. In addition, biotin, a vitamin contained in yeast extract, was shown to be necessary for appreciable root formation. Furthermore, experimental work led to the belief that an internal factor "x" was also requisite for root formation: even with all the known factors added to a root solution the number of roots formed was no greater than when one of the known factors was absent, in certain experiments. Hence, plant physiologists became convinced that there was an

(*Continued on page 348*)

The Royal Mail Ship Queen Elizabeth

By GEORGE SWALLOW, '48

ON the twenty-seventh of September, 1938, a smiling Scottish woman, watched by her family, broke a bottle on the bow of a ship at Clydebank. There was, perhaps, nothing unusual in that, for Scotland is famous for ships, but this woman was the Queen of England, and this ship was the Royal Mail Ship *Queen Elizabeth*.

Had things gone well, the new liner should have made her debut on the Western ocean two years later.

Cunard White Star Ltd.

A comfortable smoking room on the boat deck

However, war intervened, and on March 7, 1940, still incomplete, the *Queen Elizabeth* arrived in New York to stay with the other sea queens, *Normandie*, *Aquitania* and *Queen Mary*. Her stay was not long, for on November 13 she sailed for Singapore, Straits Settlements, to be converted to a troop transport. On His Majesty's Service, the *Queen Elizabeth* sailed over five hundred thousand miles and carried over eight hundred thousand men, many of whose initials may still be seen carved in her rails.

In 1946, the *Queen Elizabeth* was returned to her owners, Cunard White Star Limited. Refitting was undertaken by John Brown, her builder. Because the ship was too large to ascend the river to the place of her origin, the men and material were brought to the ship at Clydemouth. While the mechanical refitting was being carried out, the furnishings for the accommodations were gathered from the world to the Southampton Airport. In June, the ship went to Southampton for outfitting, and while there, went in to graving dock to check her underwater parts. Afterward she returned to Scotland for trials at Arran at which the Queen of England was present.

On October 16, 1946, the *Queen Elizabeth* made her maiden voyage under the flags of Cunard White Star. As she was not trying to break records, she did the voyage to New York from Southampton in slightly more than four days, the usual time required. She returned to Southampton on the thirtieth, and since then has been in regular fortnightly service.

The *Queen Elizabeth* and her sister ship, *Queen Mary*, were designed to provide two-ship weekly service on the Atlantic. Previously, the service had been maintained with three ships, the *Aquitania*, *Berengaria*, and the old *Mauretania*. The *Queens* represent the smallest possible ships which can maintain such service.

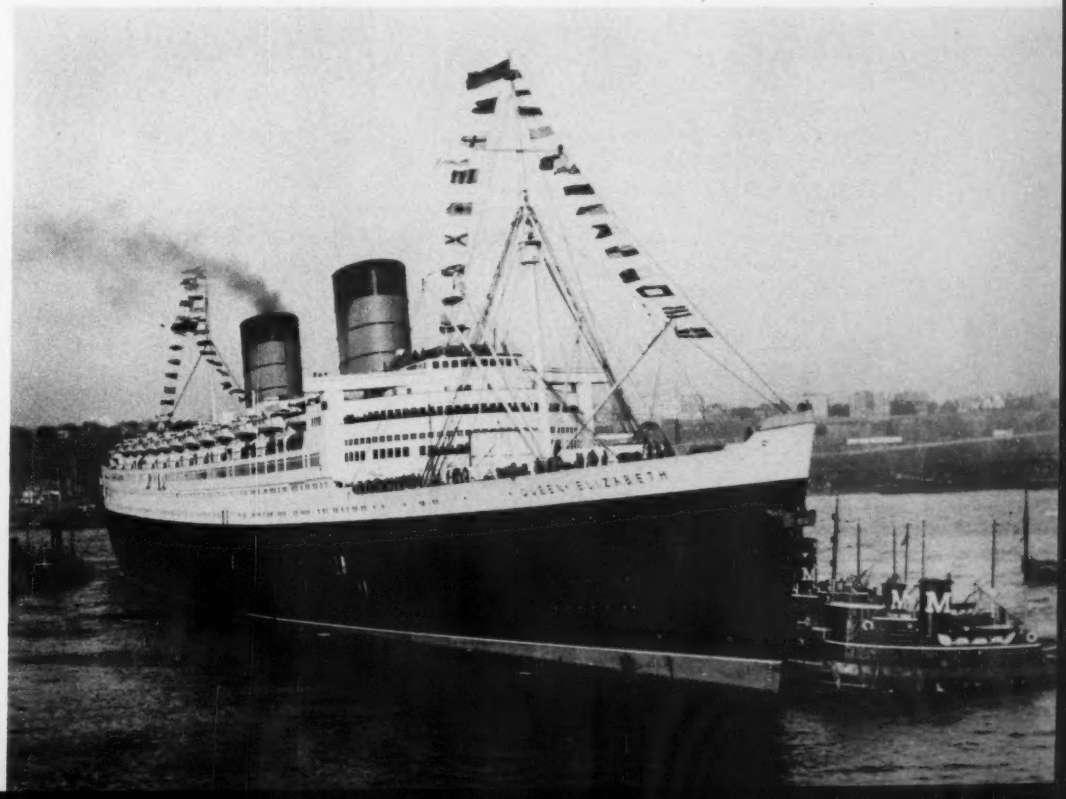
The *Queen Mary* was laid down in 1928, but was held up by the depression. She was launched in 1934, to be followed in four years by her sister ship.

It is interesting to compare the two ships, for the differences are more noticeable than the similarities. It should be noted that the later vessel had the advantages of recent developments.

The most striking difference in the ships is that the *Elizabeth* has two funnels while the *Mary* has three. A second noticeable change is that the bow of the *Elizabeth* has a rake, while the *Mary* has none. This is due to the fact that the former carries three bower anchors, port, starboard and centerline, whereas the latter has but two. Another result of the three anchors is in an increase in length of 27 feet.

The Queen Elizabeth *arriving at the Port of New York on her maiden voyage in 1946*

Cunard White Star Ltd.



The main lounge on the promenade deck *Cunard White Star Ltd.*

The engineering improvements are not noticeable externally, except as evidenced by the one less funnel. The most radical change is in the steam generating equipment. The *Elizabeth* has twelve boilers in four boiler rooms, while the *Mary* has 27 boilers in five boiler rooms.

The *Queen Elizabeth* is the largest ship in the world. She is also presumed to be the fastest. With regard to size, there can be none of the claims and counterclaims which were so common during the race before the war. In mensions and in tonnage and in displacement, the *Queen Elizabeth* is larger than the next larger ship, the *Queen Mary*. The claims about speed are only claims, as the results of her trials were withheld.

In length the *Queen Elizabeth* is 1,031 feet. For comparison, the *Queen Mary* is 1,004 feet; the *America*, 663 feet; and the old *Mauretania* was 762 feet. The *Elizabeth* is 118 feet in beam, as is the *Mary*, which precludes either ship passing through the Panama Canal. The working draught is about 44 feet, the designed draught, about 48 feet. The tonnage of the *Queen Elizabeth* is 83,673 tons, a ton here being 100 cubic feet. Her displacement is roughly 78,000 tons, in this case a ton being 2,240 pounds.

The ship is of riveted construction throughout.

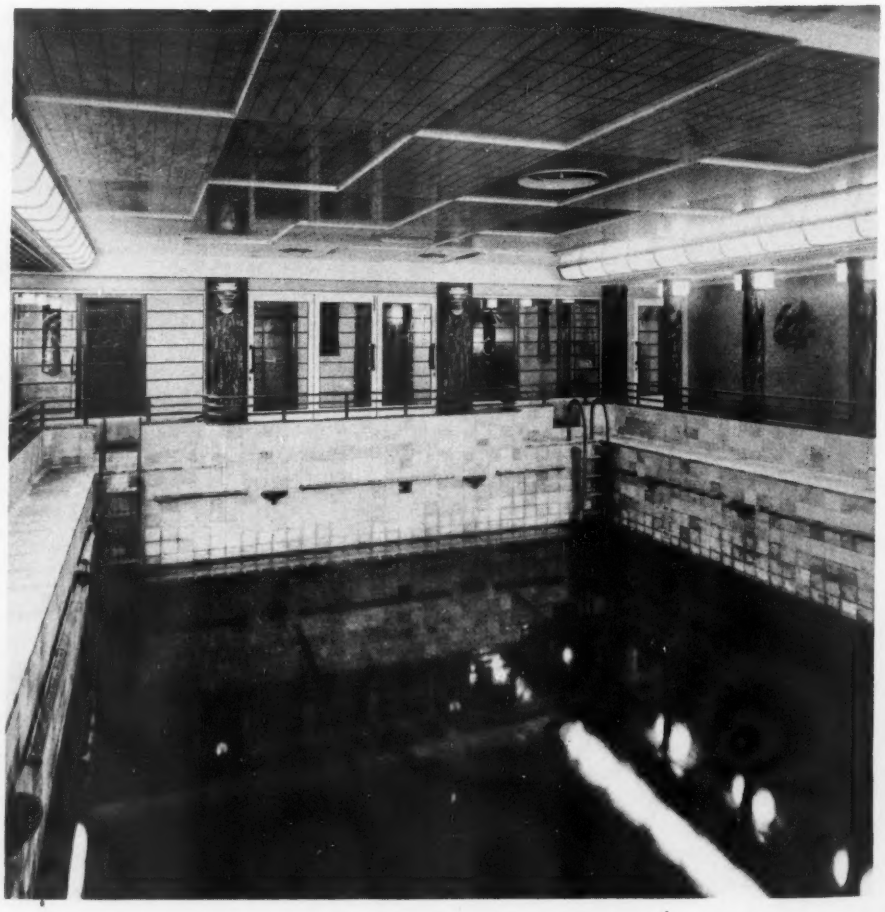
For safety, both from fire and flooding, the *Queen Elizabeth* is divided into 12 watertight compartments by athwartships bulkheads which rise to "B" deck. There is also a longitudinal bulkhead amidships in way of the generator rooms. Throughout the rest of the ship, longitudinal bulkheads are arranged to be non-watertight.

The propelling machinery of the *Queen Elizabeth* consists of 16 turbines geared to four shafts, the machinery for each shaft being independent. Each unit consists of High Pressure, First Intermediate Pressure, Second Intermediate Pressure and Low Pressure turbines with condenser. Astern turbines are included within the casings of the Second Intermediate Pressure and the Low Pressure turbines. The gearing on each unit consists of a single stage reduction accomplished by a double-helical main gear driven by four pinions, one from each turbine. The units are identical, but are oriented differently to make the most of the available space. Each unit can develop 50,000 h.p., giving the ship a maximum of 200,000 h.p.

The propelling machinery is located in two turbine rooms in the after part of the ship, the wing shafts coming into the forward turbine room, and the inboard shafts into the after room. In the forward room, the High Pressure and First Intermediate Pressure turbines are forward and the condensers inboard, while in the after room, the Second Intermediate Pressure and Low Pressure turbines are forward and the condensers are outboard.

The shafts are exposed in the single large compart-

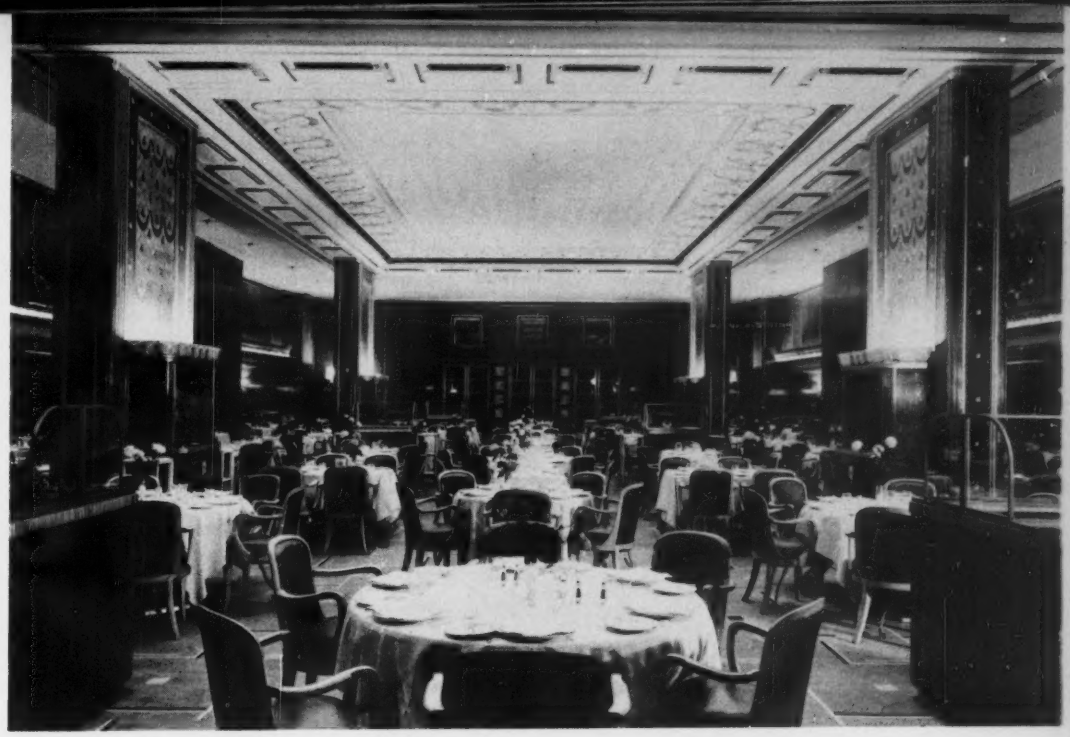
The swimming pool on "C" deck *Cunard White Star Ltd.*



ment from the after turbine room until they pierce the hull. The shafts are oil lubricated in the ship, and have water-lubricated bearings at the glands, where each shaft terminates in a four-bladed propeller of manganese bronze 18 feet in diameter and weighing 32 tons.

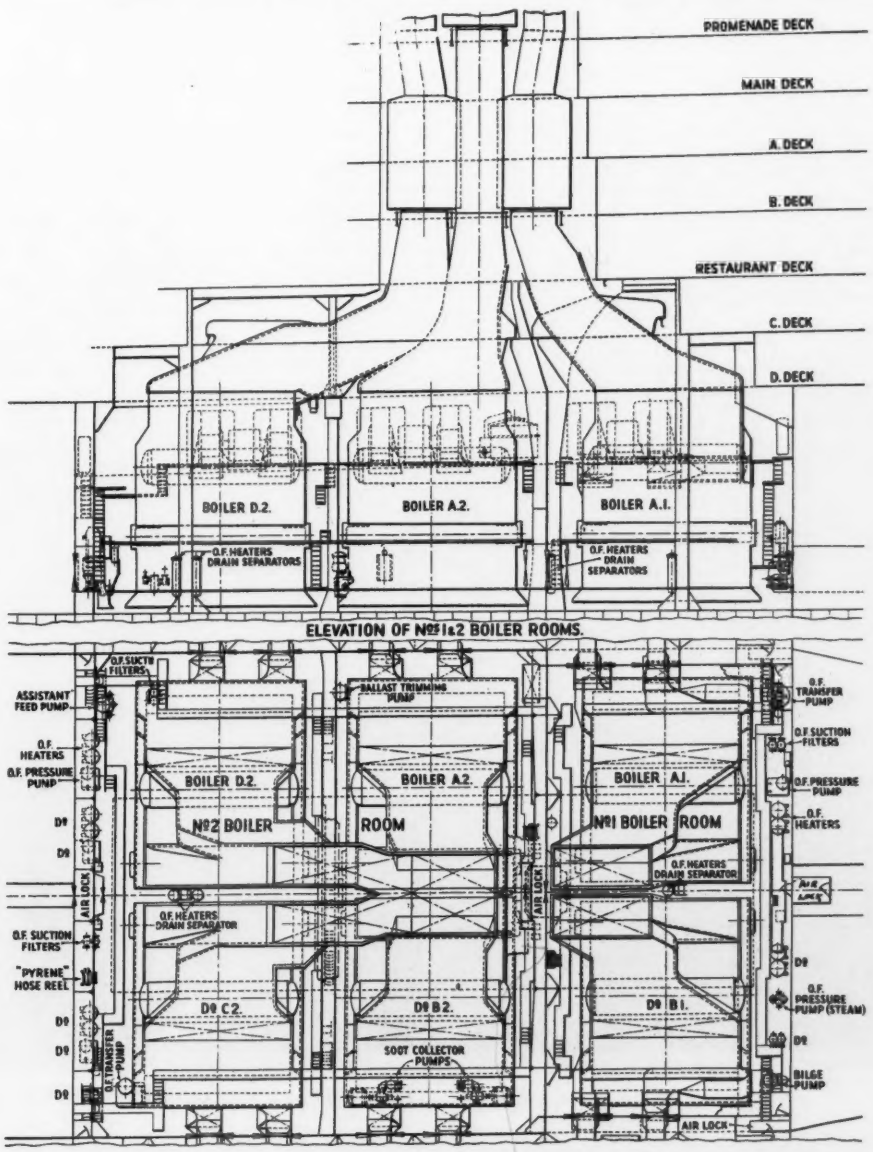
Steam for the turbines is provided by twelve Yarrow water-tube boilers equipped with superheaters and air heaters. The boilers are arranged fore and aft, and are side fired, the burners being on the centerline working alley. Each boiler has seven oil burners.

Draught is provided by the closed stokehold system. This simplifies the equipment as the boiler rooms are ventilated by the same machinery which provides the draught. The large air circulation makes the boiler rooms much cooler than similar spaces in ships with other type draught. (This is a matter of personal observation. The boiler rooms are not uncomfortable, though warm, even with winter clothing.) However, the closed stokehold system does require some means of keeping the entrances air tight. On the *Queen Elizabeth* this is done by means of air locks at the entrances into the boiler spaces and on the centerline passage between boiler rooms. The gases from the boilers are passed through wet-type dust collectors to remove soot and ash before being discharged through the two funnels, 45 feet above the uppermost deck.



The main restaurant on "R" deck *Cunard White Star Ltd.*

The forward boiler rooms of the Queen Elizabeth. *Above, a section through the port side parallel to the centerline. Note the six uptakes in a single funnel. Below, a plan view of the boiler rooms, which do not extend to the side of the ship, as may be seen from the plan. Note the centerline passage and the air locks* *Shipbuilding and Shipping Record*

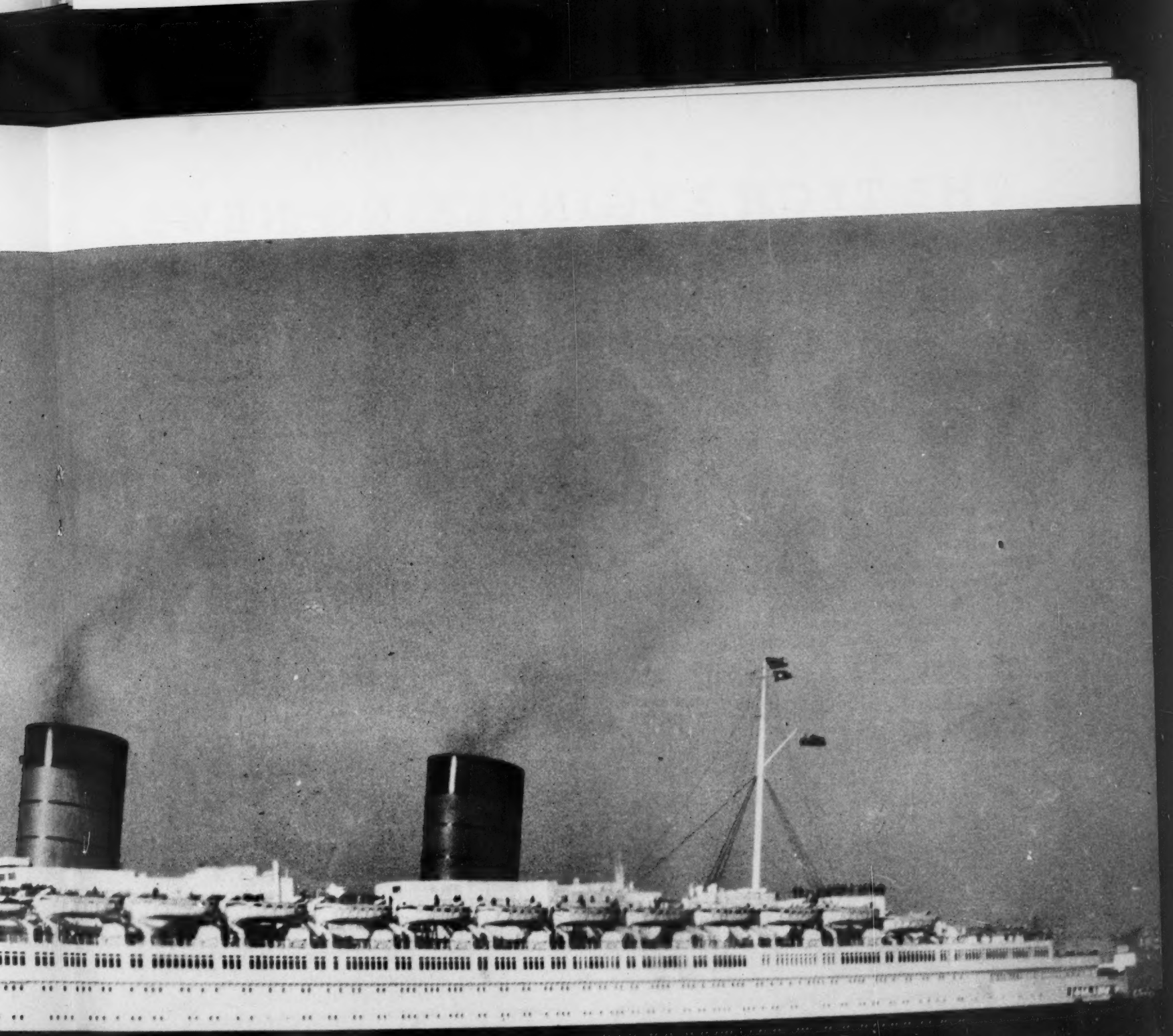


The electrical system of the ship is unusually extensive. The hotel services are all electrical, as is *all* the machinery, with the exception of the propulsive machinery, the generators, and the main feed pumps. The electricity is supplied by four turbo-generators located in two compartments amidships on "G" deck. Each generator consists of two 1,100 kw. dynamos driven in

(*Continued on page 346*)

The Queen Elizabeth steaming down New York City's North River

Cunard White Star Ltd.



THE TECH ENGINEERING NEWS

MANAGING BOARD

JOHN W. WEIL, '48
General Manager

EDWARD M. KOSOWER, '49
Editor-in-Chief

WILLIAM C. NEMITZ, '49
Business Manager

PETER E. PICCOLI, '48
Managing Editor

JUNIOR BOARD

EDWARD T. MILLER, '49
Make-Up Editor

PETER JOHNSON, '50
Features Editor

GUIDO J. FRASSINELLI, '48
Treasurer

EDNA MULLER, '48
Circulation Manager

EDWARD A. MULLERY, '48
Advertising Manager

WILLIAM PRICE, '50
Sales Manager

STAFF

WILLIAM R. BOHLMAN, '49
RICHARD NELSON BOLLES, '50
MARIO DI QUILIO, '49
RICHARD VICTOR DYBA, '50
FLETCHER EATON, '49
WILLIAM A. FARMER, '50
ROY W. JENKINS, '50
RALPH JOHNSTON, '50
HERBERT KURINSKY, '48
PETER B. NEIMAN, '49
PEDRO PICORNELL, '47
JOSEPH M. RAULT, '48
WILLIAM RAICH, '49
LEO SARTORI, '50
V. SIMPSON, '50
RICHARD W. SPENCER, '48
THOMAS SWALLOW, '48
HARRISON WHITE, '50
KENNETH WIBERG, '48
DAVID S. YABLONG, '47

MEMBER ENGINEERING COLLEGE MAGAZINES ASSOCIATED

ARKANSAS ENGINEER
CINCINNATI COOPERATIVE ENGINEER
COLORADO ENGINEER
CORNELL ENGINEER
DREXEL TECHNICAL JOURNAL
ILLINOIS TECHNOGRAPH
IOWA ENGINEER
IOWA TRANSIT
KANSAS ENGINEER
KANSAS STATE ENGINEER
KENTUCKY ENGINEER
MARQUETTE ENGINEER
MICHIGAN TECHNIC
MINNESOTA TECHNO-LOG
MISSOURI SHAMROCK
NEBRASKA BLUE PRINT
NEW YORK UNIVERSITY QUADRANGLE
OHIO STATE ENGINEER
OREGON STATE TECHNICAL RECORD
OKLAHOMA STATE ENGINEER
PENNSYLVANIA TRIANGLE
PURDUE ENGINEER
ROSE TECHNIC
TECH ENGINEERING NEWS
WAYNE UNIVERSITY ENGINEER
WISCONSIN ENGINEER

Chairman
WAYNE S. BEATTIE
University of Colorado
Boulder, Colorado

Advertising Representative
LITTELL MURRAY BARNHILL, INC.
101 Park Avenue, New York
605 North Michigan Avenue, Chicago

Can You Do It?

THE TENTH IN A SERIES OF MONTHLY BRAINBUSTERS

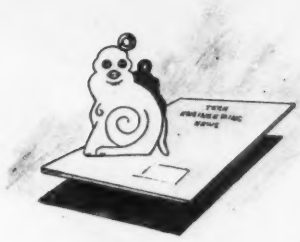
THIS MONTH: A pair of unique problems . . .

Problem 1: A man is walking across a railroad bridge. When he is three-eighths of the way across, he hears a train coming. If the train is coming at sixty miles per hour, and if he can just run off either end of the bridge to safety before the train catches him, how fast can he run?

Problem 2: A man who carries a watch in which the hour, minute, and second hands turn upon the same center was asked the time of day. He replied, "The three hands appear at equal distances from one another and the hour hand is exactly 20-minute spaces ahead of the minute hand." Can you tell the time? — "*Mathematical Wrinkles*" *by S. I. Jones.* J.W.W.

Answers to both the April and May problems are on page 342.

The Dragon's Den



Progress . . .

. . . the little god o' the world sticks to the same old way,
and is as whimsical as on Creation's day.

Life might somewhat better content him,
But for the gleam of light which Thou hast lent him:
He calls it Reason, — thence his power's increased
To be far beastlier than any beast. . . .
MEPHISTOPHELES: FAUST — GOETHE.

Another major advance is in the offing for the science of extinction: Glenn Martin has testified before a Senate Committee that the Army and Navy are experimenting with radioactive vapors capable of cancelling life in a large ground area for a long period of time. At the same time, Mr. Martin, who as head of Martin Aircraft is certainly in a position to know, told reporters that his factories were building rockets for the Navy as well as guided missiles which are able to attain a height of 236 miles in vertical flight. This information is illuminating: Soon we will have guided missiles which can carry "superior" atomic bombs for tremendous distances, first-class ingredients for a war. At this same committee meeting, Senators and witnesses referred freely to Russia as a potential enemy. Navy seers are doing an excellent job of crystal-gazing. But do not think that their counterparts in the Army are far behind: General Eisenhower recently created a special "Buck Rogers" planning board for atomic warfare. When questioned on his attitude toward Russia, the General cracked, "Firmness, patience, a sense of humor, and keep your powder dry." In that order, we wonder?

In Europe, Winston Churchill, spiritual leader of the English Conservatives, proposed his plans for a United Europe, and indicated that Russia and the Russian-dominated Eastern European nations would not be welcome except under conditions set by the movement's organizers. His audience was assured that the United States would bestow blessings on his plan, possibly in the same way that it approved tacitly of another Churchill speech on Anglo-American alliance made at Fulton, Missouri last year.

The future is bright for those engineers and scientists who appreciate the nuances and fine points of a life devoted to developing weapons for war. Our military has become convinced of the infallibility of their scientists; they are now planning policies based on the irrefutability of this dogma.

Over the fog of "united" nations activities frowns a war god of black and forbidding mien; while, relentlessly, Americans, including a good proportion of our "intelligent" engineering and scientific population, are being led to the guillotine. Science recognizes no national boundaries and moves freely about the world. Our opponents, real or imagined, may not be as well-developed as we, but we too will suffer the consequences of not keeping the peace.

* * * *

When an upright pillar of the journalistic world like the *New York Times* must stoop to petty word-juggling and catch-phrases on any matter, then it is a matter which must be looked into very carefully. The *Times* editorial writer flailed mightily away at William Green, President of the AF of L without convincing even himself that Mr. Green's fears over the Taft-Hartley labor legislation were completely unfounded. When a bill in effect removes all or most of the advantages that labor has enjoyed for the past ten years, then it is indeed something for labor to worry about. The *Times* writer claims that these laws are a step toward equalizing labor-management responsibility. Does that include sharing the profits, along with the so-called responsibility?

* * * *

Parochial schools are currently engaged in a dogfight for Federal aid. Does the denomination of the engineering religion located at M. I. T. also rate subsidy? We ought to be clever enough to get on *this* bandwagon for bringing state and religion more closely together.

E. M. K.

Smörgåsbord for Boilers...

Coal, gas, and oil (fired singly or in combination) are regular items on today's menu for B&W boilers. Occasional entrees include: grain hulls, wood chips, asphalt, sewage sludge, by-products of paper mills, steel plants and sugar mills...just about anything that burns. So B&W builds boilers and combustion equipment that burn what's available today... likely to be available tomorrow... at top efficiency.

Helping power plants to get the most from available fuels is only one of the things long years have taught B&W to do well. Industry offers examples of many others—proof of the imaginative engineering at B&W.

Through this policy of continuous development and research, B&W offers excellent career opportunities to technical graduates...in diversified fields of manufacturing, engineering, sales and research.

THE BABCOCK & WILCOX CO. 85 LIBERTY STREET NEW YORK 6, N. Y.

TWO-MILLION-VOLT X-RAYS

(Continued from page 318)

first high-velocity electrons have expended their energy and stopped. This depth is about 3 mm. for two-million-volt radiation, and about 3 cm. for twenty-million-volt rays. This is the so-called subcutaneous effect, which makes possible a substantially increased tumor dose with no increase in skin dose.

Another important effect of increasing the voltage into the million-volt range is the reduction of scattering and absorption. At 200 kv., scattered energy consists largely of the softer x-rays, which have considerable range in tissue; while at one million volts the scattered energy consists principally of electrons, the range of which is relatively short.

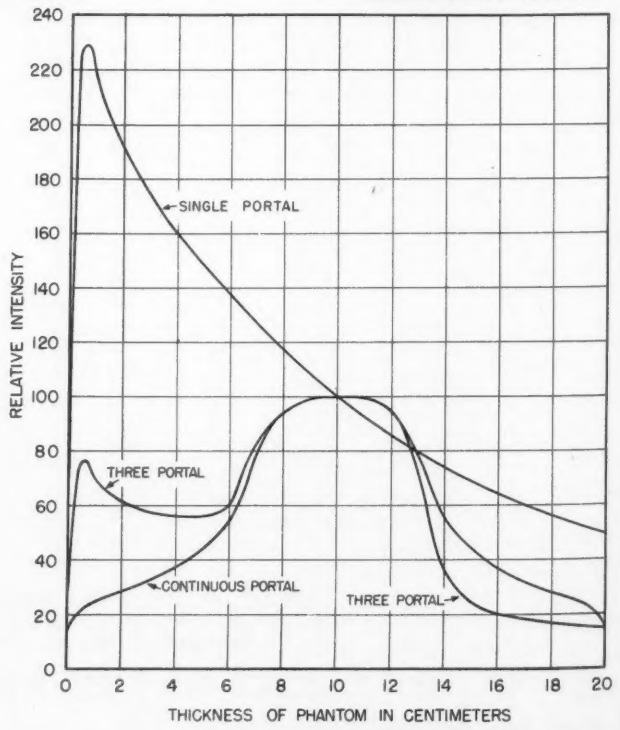
While back-scattering amounts to 36 per cent of the incident radiation at 200 kv., at one million volts it amounts to about seven per cent, and at two million volts, about three per cent. This reduction of scattering accounts for the higher depth dose which may be secured by radiation in the million-volt range. For treatment with a 10×10 cm. field at a treatment distance of one meter, the depth dose at a 10-cm. depth increases from 35 per cent of the incident radiation for 200-kv. rays to 46 per cent for one million, 52 per cent for two million, 57 per cent for three million, and 61 per cent for four million volts.

Another factor limiting treatment with x-rays is the exit dose — the radiation received by the skin on the far side of the body due to rays passing through. Fortunately, this dose can be reduced to safe values even with rays of several million volts by inverse-square-law intensity reduction and by absorption. At a one-meter

(Continued on page 340)

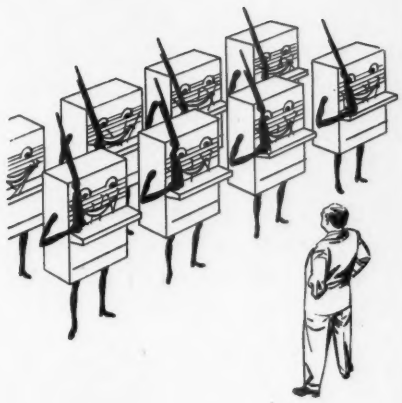
Figure 5. Distribution of ionization along a beam axis using 2.0-million-volt Roentgen rays at 100 centimeters distance. The filtration is equivalent to that of 9 mm. of lead for the cases of single portal, three portal, and continuous portal irradiation with a 5 cm. × 5 cm. beam. A round phantom of 20 centimeter diameter is utilized

Electrical Engineering Department



NUMBER 7 OF A SERIES

Newsworthy Notes for Engineers



Rigid Inspection is the rule

Bell Telephone equipment, being precision apparatus, must stand inspection during each stage of its manufacture. Materials being used in manufacture . . . parts in process . . . partial assemblies . . . equipment after it is assembled and wired . . . all must be checked and rechecked to insure high quality of performance.

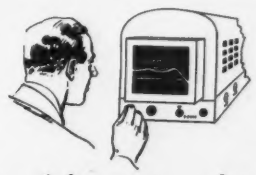
The design and maintenance of test equipment for such a wide variety of products calls for men with technical training and inventive resourcefulness.

This equipment must be fast and accurate in operation, and although it may be complex in design and construction, it must be simple to operate by the average worker. And, to facilitate mass production, test equipment of many different types is also required.

Here are just a few interesting examples of the many test sets Western Electric engineers have developed to meet these needs.

What's wrong with which wire?

Formerly, when switchboard cables failed to pass inspection, it was often difficult to determine which conductor was causing the trouble and what the exact nature of the trouble was. Not any more. Now, Western Electric engineers have developed a new test set that checks switchboard cables for the continuity of each wire . . . that checks the dielectric strength between each wire and every other wire and the ground shield. It automatically tests a cable of up to 320 conductors for continuity and insulation resistance in a total testing time of 35 seconds! If a defect is present, the faulty conductor and the type of defect is indicated visually.



Looking at voices

A new method for testing the volume efficiency of telephone receivers has been introduced since the end of the war. Now, the output of a 0-3000 cycle per second, slow sweep band frequency oscillator is applied to the receiver and its output depicted upon a long persistence screen of an oscilloscope. Thus, an inspector can *see* the complete frequency response curve of the receiver under test and quickly classify defective receivers according to the nature of the defect.

Find the pinhole!

In the manufacture of coils for relays, ringers, etc., Western Electric uses tremendous amounts of enameled wire. The quality of this insulating enamel must be of the highest. So Western Electric developed a "pinhole" test set which reliably detects the most minute imperfections in the enamel coating as soon as it comes from the baking oven. This instrument helps greatly in maintaining quality standards and in establishing satisfactory sources of supply.

Is it cracked on the inside?

In wartime especially, a large volume of non-ferrous rod stock was used. Testing it for internal flaws became imperative, yet no manufacturer of such stock had devised any method. Western Electric engineers came through with a device to do the job. One that not only located objectionable cracks and determined their thickness but also served as a precise thickness gauge for such materials as aluminum condenser foil . . . detecting differences of a fraction of a millionth of an inch in foil nominally two hundred millionths of an inch thick.

Manufacturing telephone and radio apparatus for the Bell System is Western Electric's primary job. It calls for engineers of many kinds — electrical, mechanical, industrial, chemical, metallurgical — who devise and improve machines and processes for large scale production of highest quality communications equipment.

Western Electric

A UNIT OF THE BELL SYSTEM SINCE 1882

*The first boat powered by steam, built by William Henry, and tested on the Conestoga River, near Lancaster, Pa., in 1763.

Management and work were needed to build the first steamboat*

Even the genius of William Henry — who helped emancipate man from the drudgery of hand labor — would have achieved nothing without sound management. Maker of the famous "Kentucky Rifle," Henry was also an able inventor of labor saving machines. In 1763, he built the world's first steamboat, that later inspired Robert Fulton. Henry combined management ability with imagination and energy to build a successful business. He typified the qualities that has made America productive.

Without able management to harness our inventive genius, and make it useful, our economy would still be back in the stage of primitive household industries. Sound management has transformed scarcity into abundance . . . has made possible a large population that enjoys the world's highest standard of living. How far we go from here may easily depend upon how well everyone appreciates the old fashioned virtues. Even able management can achieve little unless an honest day's work is given for a day's wages.

• • •

Steam transportation became modern and efficient only when friction in moving parts was conquered. In this development, SKF ball and roller bearings have played a major role. Made in many sizes and types, SKF bearings prove in steamships throughout the world that they are:

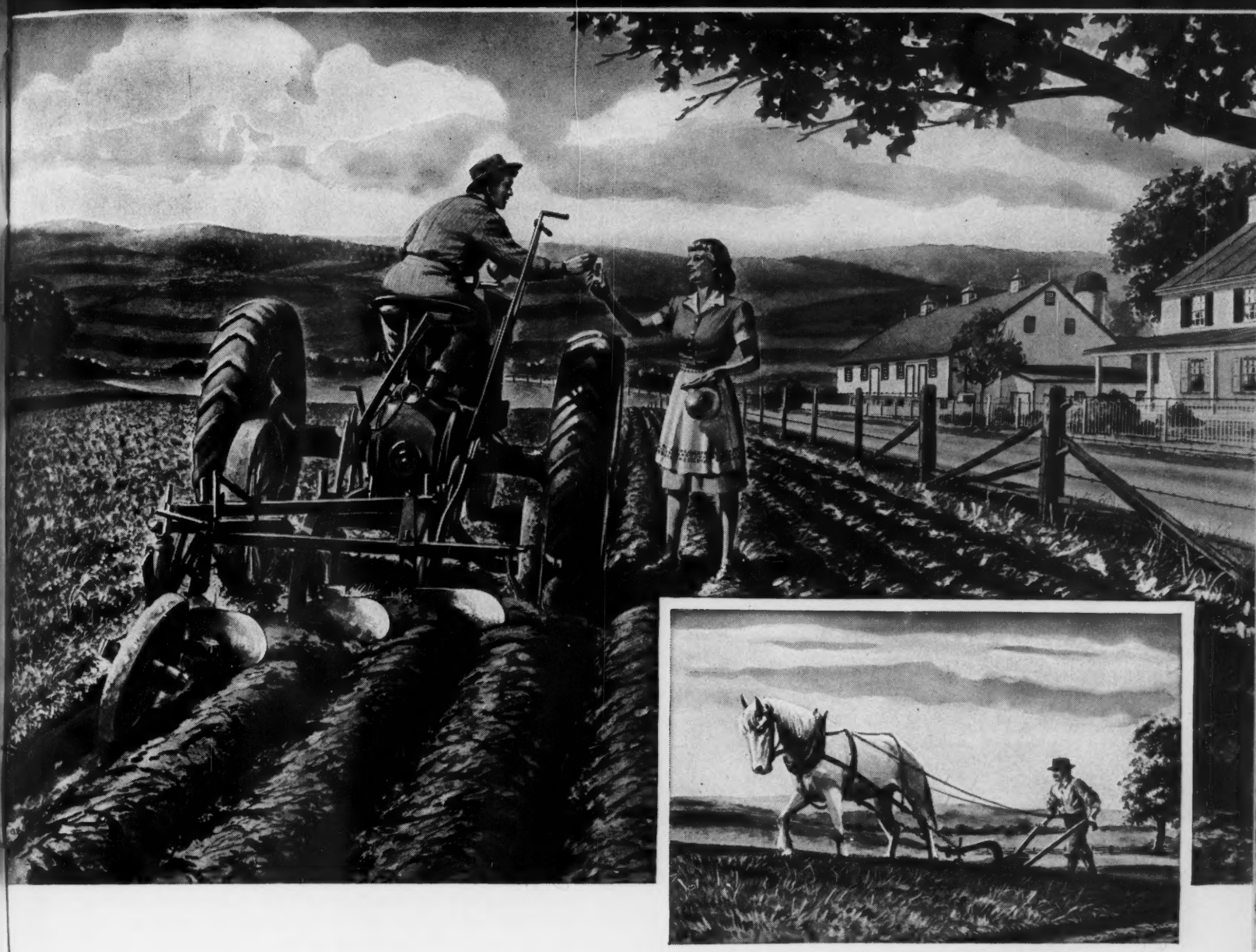
THE RIGHT BEARING FOR THE RIGHT PLACE

SKF
BALL AND ROLLER
BEARINGS

7012-A

SKF INDUSTRIES, INC., PHILA., PA.

"What is all knowledge . . . but recorded experience?"—CARLYLE



Why some things get better all the time

HEALTH, strength and zest for life—of youngsters, of workers, of all of us—depend on food. Food produced by the millions of tons yearly. And each year our farmers have *more efficient means* to do their tremendous job.

The modern farmer has a tractor, a truck, and uses specialized farm tools—all with parts made increasingly of alloy-toughened steels and of plastics, for sturdier, more efficient service. His milking machine has parts of rust-resistant stainless steel. Chemically fortified feeds grow healthier livestock. New chemical sprays protect his crops from insects and plant diseases. And improved fertilizers restore vital elements to his soil.

From care of the life-giving soil to precious harvest, the farmer's means for food production are steadily improving . . . because into these means go *better and better materials.*

Producing better materials for the use of science and industry and the benefit of mankind is the work of UNION CARBIDE.

Basic knowledge and persistent research are required, particularly in the fields of science and engineering. Working with extremes of heat and cold—frequently as high as 6000° or as low as 300° below zero, Fahrenheit—and with vacuums and great pressures, Units of UCC now separate or combine nearly one-half of the many elements of the earth.

UNION CARBIDE
AND CARBON CORPORATION

30 EAST 42ND STREET UCC NEW YORK 17, N. Y.

Products of Divisions and Units include

LINDE OXYGEN • PREST-O-LITE ACETYLENE • PYROFAX GAS • BAKELITE, KRENE, VINYON, AND VINYLITE PLASTICS
ACHESON ELECTRODES • EVEREADY FLASHLIGHTS AND BATTERIES • NATIONAL CARBONS
PRESTONE AND TREK ANTI-FREEZES • ELECTROMET ALLOYS AND METALS • HAYNES STELLITE ALLOYS • SYNTHETIC ORGANIC CHEMICALS

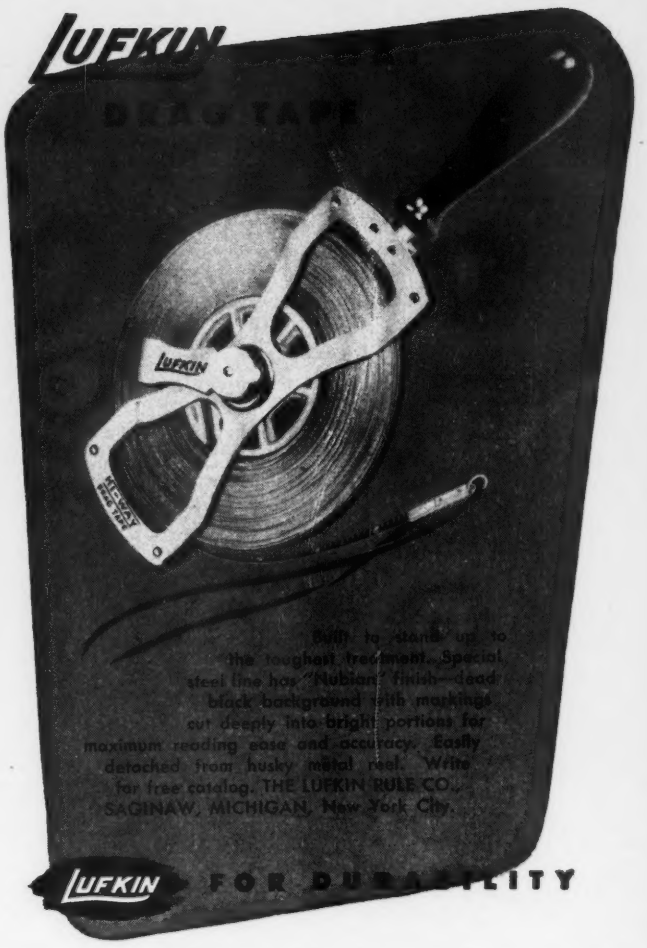
short facts about long-lived cable

• Only washed Wild Up-river Fine Para rubber is used in Okonite insulation. The Okonite Company, Passaic, New Jersey.

look for the single ridge

OKONITE

insulated wires and cables for every electrical use



TWO-MILLION-VOLT X-RAYS

(*Continued from page 336*)

treatment distance with a 10×10 cm. field, the exit dose at a depth of 20 cm. is about 11 per cent of maximum for 200-kv. rays, 22 per cent for two-million-volt rays, and 28 per cent for three-million-volt rays. These values are sufficiently small to avoid serious skin reactions.

Rays of much more than a few million volts will cause too high an exit dose, however. At 20 million volts with the distances mentioned above, the exit dose is 65 per cent of the maximum dose. Shorter treatment distance could partially remedy this, but would introduce non-uniformity of field due to the narrow beam width characteristic of such high-voltage radiation.

The constant-potential x-rays used in the Institute's physico-medical program are produced by a pressure-insulated Van de Graff generator constructed at M.I.T. several years ago. This source produces steady, continuous electron streams of homogeneous intensity, controllable over a wide voltage range. In this particular apparatus, the range available for study is approximately from one half to four million volts. The target is of gold, 4 mm. in thickness, and water-cooled. The rays passing through the target in the direction of the electron stream, defined into a beam by lead diaphragms, are utilized. The diaphragm system should be far enough from the skin so that the electrons produced by the rays striking it will be scattered before reaching the skin. In this setup the bottom surface of the diaphragm system was located about 50 cm. from the target, and the treatment distance was one meter.

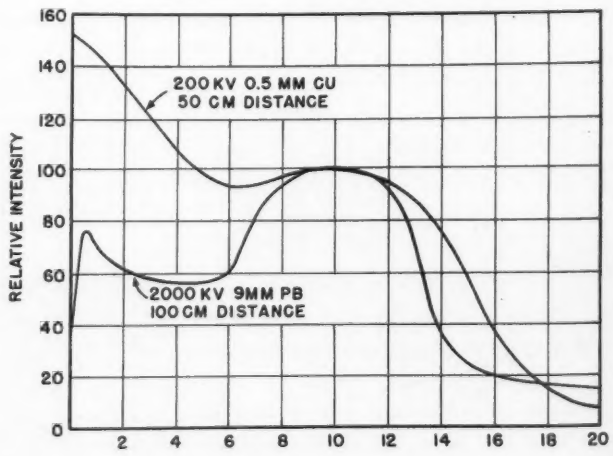
A "phantom" of Masonite Presdwood, specific gravity 1.02, mounted on a remote-controlled carriage, was used to simulate tissue. Two ionization chambers, one imbedded in the phantom, the other as a control situated in the center of the beam above the phantom, were used, equipped with an electrometer measuring circuit.

Figures 3 and 4 are isodose charts for two-million-volt constant-potential x-rays filtered by the equivalent of 9 mm. of lead. Treatment (target to phantom) dis-

(*Continued on page 342*)

Figure 6. Comparison of three portal cross-firing with filtered 200 KV and 2000 KV radiation. Curve shows the ionization density along one beam axis for three portal cross-firing into a 20 cm. round phantom. The beams are 5 cm. × 5 cm. at the surface. Values are calculated from single portal isodose measurements

Electrical Engineering Department



Television gives you a choice seat at the game.

Television—a Season Pass to Baseball !

Every home game—day or night—played by the New York Giants, Yankees and Brooklyn Dodgers will be seen over television this season!

Owning a television receiver in the New York area will be like having a season pass for *all three ball clubs*. And in other cities, preparations for the future telecasting of baseball are being made.

When more than one home game is on the air, baseball fans can switch from one to the other—see the most exciting moments of each through television!

Those who own RCA Victor television receivers will enjoy *brighter, clearer, steadier* pictures through the RCA Victor Eye-Witness picture synchonizer that "locks" the receiver in tune with the sending station.

To witness baseball or any other event in the ever-growing range of television programs—you'll want the receiver that bears the most famous name in television today—RCA Victor.

When you buy an RCA Victor television receiver or radio, or Victrola radio-phonograph, or an RCA Victor record or a radio tube, you know you are getting one of the finest products of its kind science has achieved.

Radio Corporation of America, RCA Building, Radio City, New York 20. Listen to the RCA Victor Show, Sundays, 2 p.m., Eastern Daylight Time, NBC Network. "Victrola" T.M. Reg. U.S. Pat. Off.

Continue your education with pay—at RCA

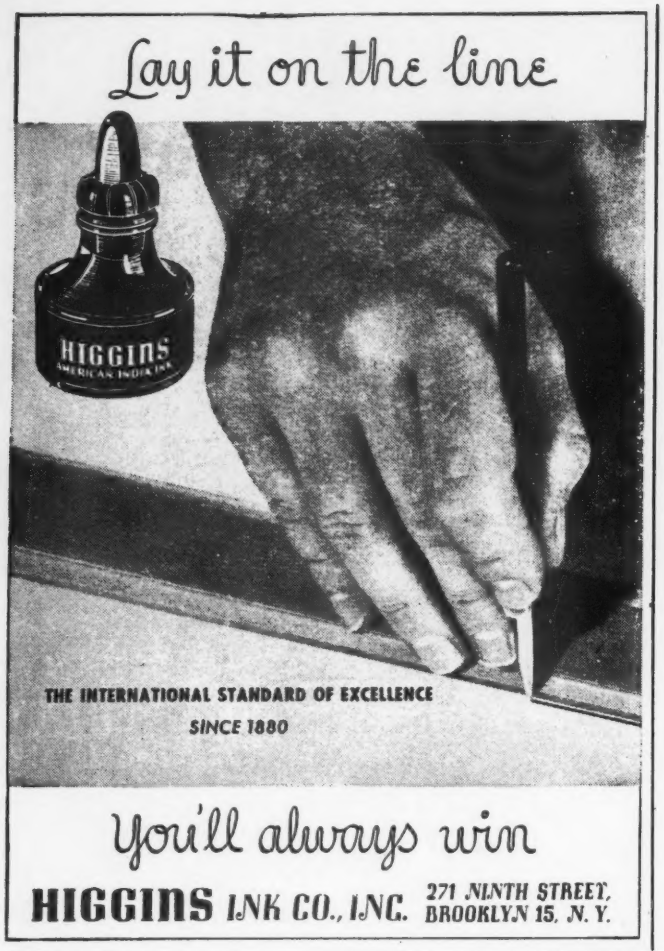
Graduate Electrical Engineers: RCA Victor—one of the world's foremost manufacturers of radio and electronic products—offers you opportunity to gain valuable, well-rounded training and experience at a good salary with opportunities for advancement. Here are only five of the many projects which offer unusual promise:

- Development and design of radio receivers (including broadcast, short wave and FM circuits, television, and phonograph combinations).
- Advanced development and design of AM and FM broadcast transmitters, R-F induction heating, mobile communications equipment, relay systems.
- Design of component parts such as coils, loud-speakers, capacitors.
- Development and design of new recording and reproducing methods.
- Design of receiving, power, cathode ray, gas and photo tubes.

Write today to National Recruiting Division, RCA Victor, Camden, New Jersey.

Also many opportunities for Mechanical and Chemical Engineers and Physicists.

RCA **RADIO CORPORATION of AMERICA**


Lay it on the line
HIGGINS
AMERICAN INDIA INK
THE INTERNATIONAL STANDARD OF EXCELLENCE
SINCE 1880
You'll always win
HIGGINS INK CO., INC. 271 NINTH STREET, BROOKLYN 15, N. Y.

TWO-MILLION-VOLT X-RAYS

(*Continued from page 340*)

tance is one meter. Two field sizes, 10×10 cm. and 5×5 cm. are illustrated in Figures 3 and 4, respectively. It will be noted that the maximum dosage is at a definite depth below the surface, and that the beam suffers little sidewise scattering. With the 10×10 cm. field at 10 cm. depth. the dose was 50 per cent while for the 5×5 cm. field it was well over 40 per cent.

Due to the advantage of spatial distribution of intensity of the two-million-volt rays over that of the 200-kv. rays, improved clinical procedures should become possible with the use of super-voltage equipment. It is quite probable that irradiation of a tumor by a single two-million-volt beam may often be superior to 200 kv. irradiation through many portals.

Figure 5 shows the distribution of dose through the cylindrical phantom 20 cm. in diameter irradiated by two-million-volt rays at a treatment distance of one meter, with a 5×5 cm. field at the skin. A filter was used which was equivalent to 9 mm. of lead. The curves show the ionization distribution along the beam axis for one portal, three portals, and continuous rotation.

Data for the single portal curve was obtained from direct measurement, and that for the multiportal curves was calculated from the isodose curves of figure 4. For the multi-portal treatment, the intensity distribution is nearly constant within the tumor volume. For continuous cross-firing, the skin dose was only 16 per cent of the tumor dose 5 cm. below the skin, less than 4 cm. from the "tumor" the intensity was less than 50 per cent of the tumor dose.

Figure 6 contrasts three-portal cross-firing of two-million-volt rays with that of 200 kv. rays. As can be

(*Continued on page 348*)

Can You Do It?

ANSWERS TO PROBLEMS

APRIL ISSUE:

Problem 1: While there is no strictly mathematical method for attacking this problem, simple logic can easily disclose the required digits. For instance, the first digit, a, cannot be anything expect a 1. Similarly. b must be 4 or below. Continuing along this line, a set of interlocking conditions can be set up which, after a few trials, will show that the desired six-digit number is 1 4 2 8 5 7.

Problem 2: This one is a bit more difficult. Realizing that the plow moves with a speed inversely proportional to the depth of the snow — and thus inversely proportional to the time, t — we may set up the equation

$$\frac{dx}{dt} = v = K\frac{1}{t}$$

where x is the distance traversed in the time t. If we now say that the plow started at the time T after it began to snow, we may integrate this equation between the limits of x equal to (0) to (2) and t equal to (T) to (T+60). This gives us a value for K, which is

$$K = \frac{2}{\ln\left(\frac{T+60}{T}\right)}$$

We may now integrate between our second set of limits, with T going from (T+60) to (T+120) and x going from (2) to (3). We then have the equation

$$1 = \frac{2}{\ln\left(\frac{T+60}{T}\right)} \ln\left(\frac{T+120}{T+60}\right)$$

Performing a little horse-work and solving for T, we find that the plow started moving about 37 minutes after the snow began. Thus, it started snowing at 11:23 a.m.

MAY PROBLEMS:

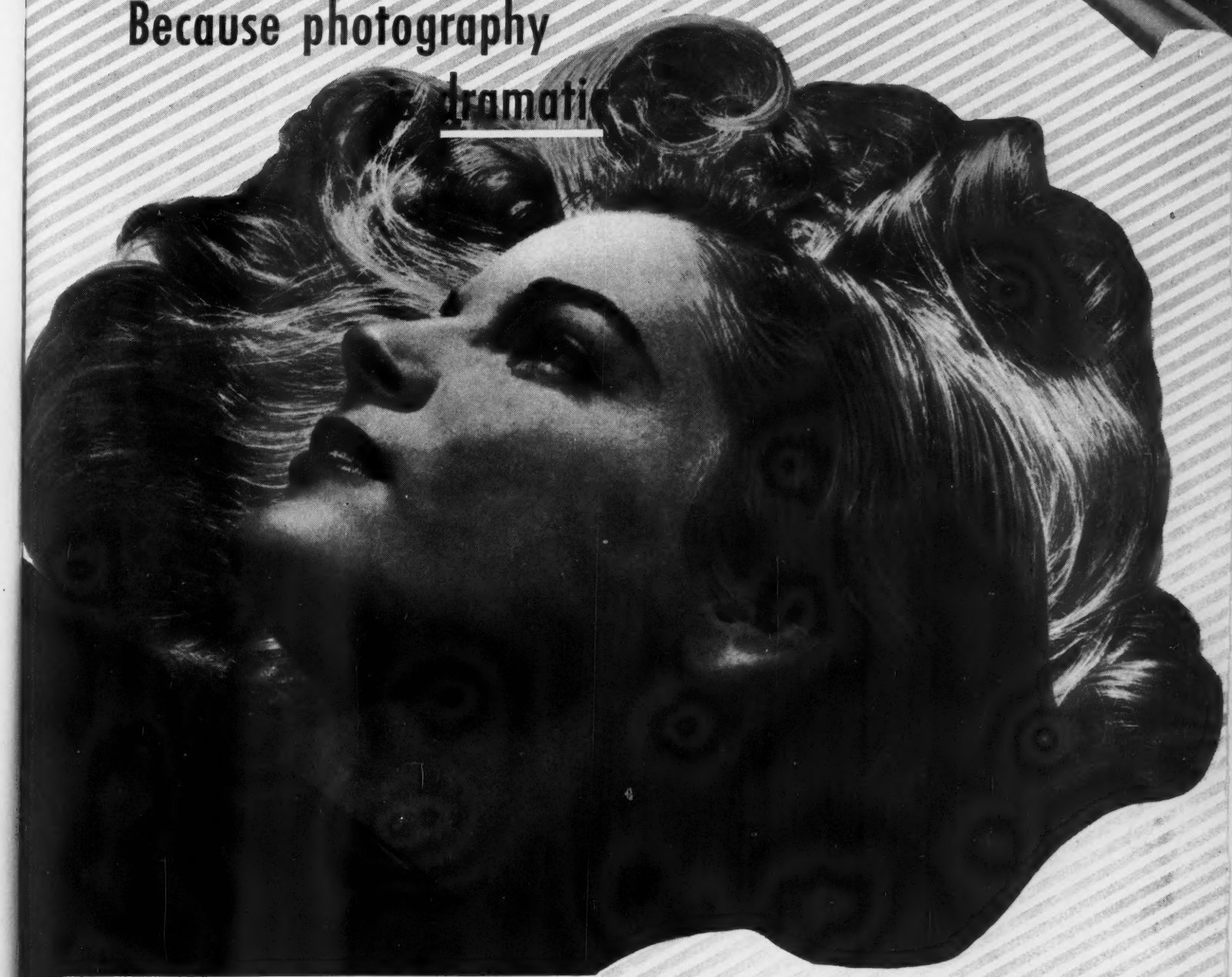
Problem 1: If the man runs off the short end of the bridge — that is, towards the train — he will get off just as the train reaches the beginning of the bridge. If, on the other hand, he runs off the other end, he and the train will reach the end of the bridge at the same time. The difference in running distance for the man is one quarter of the bridge. At the same time the train's difference in running distance is the entire length of the bridge. Thus the man is running at a speed one quarter that of the train, or fifteen miles per hour.

Problem 2: There are eleven times in twelve hours when the hour hand is exactly twenty minute spaces ahead of the minute hand. If we start at four o'clock and keep on adding 1 hour 5 minutes 27 3/11 seconds, we shall get all there eleven times, the last being 2 hours, 54 minutes, 32 8/11 seconds past twelve. Another addition brings us back to four o'clock, but at this time the second hand is nearly twenty-two minute spaces behind the minute hand, and if we examine all our eleven times, we shall find that only in one case is the second hand the required distance. This time is 54 minutes, 32 8/11 seconds past two o'clock. — "*Mathematical Wrinkles*" *by S. I. Jones.*

J. W. W.

Kodak

Because photography dramati



YOU KNOW what can be done with photography to dramatize beauty. But do you know what can be done with it to dramatize ideas . . . products . . . processes . . . technics?

With eye-arresting photographic illustrations in your advertising . . . with motion pictures . . . you can add color, spark, interest to the presentation of any idea or product. Get quicker and greater acceptance through your showmanship!

With movies and slide films, you can dramatically explain the whys and wherefores of basic processes and technics . . . make training programs more understandable, more interesting, and, therefore, more productive.

Beyond these, there are many other uses to which business and industry can put photography. For a brief description of some of these uses, write for our new, free booklet—"Functional Photography."

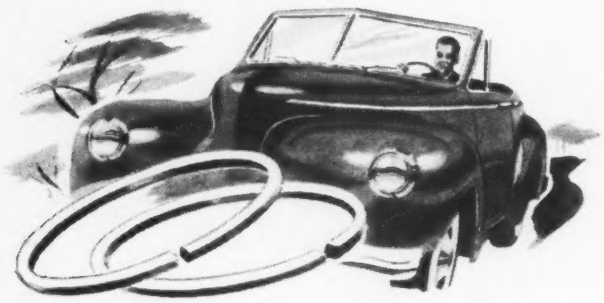
EASTMAN KODAK COMPANY
Rochester 4, New York

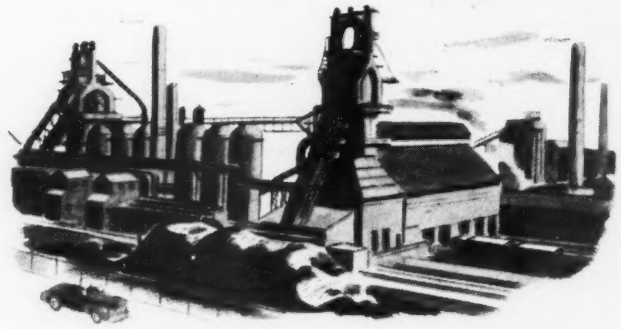
Functional Photography

Advancing business and industrial technics

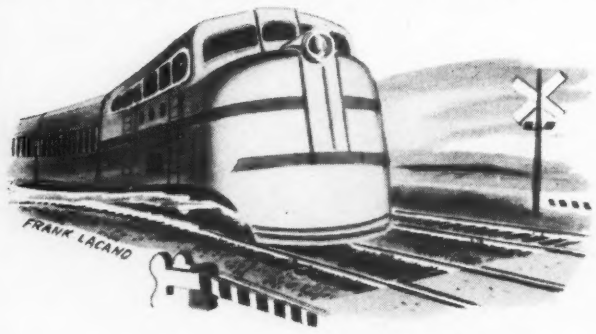
How many times did we meet today?

When you took your shower [1] . . . and combed your hair [2] . . .





drove your automobile [3] . . . . . passed a steel mill [4] . . .



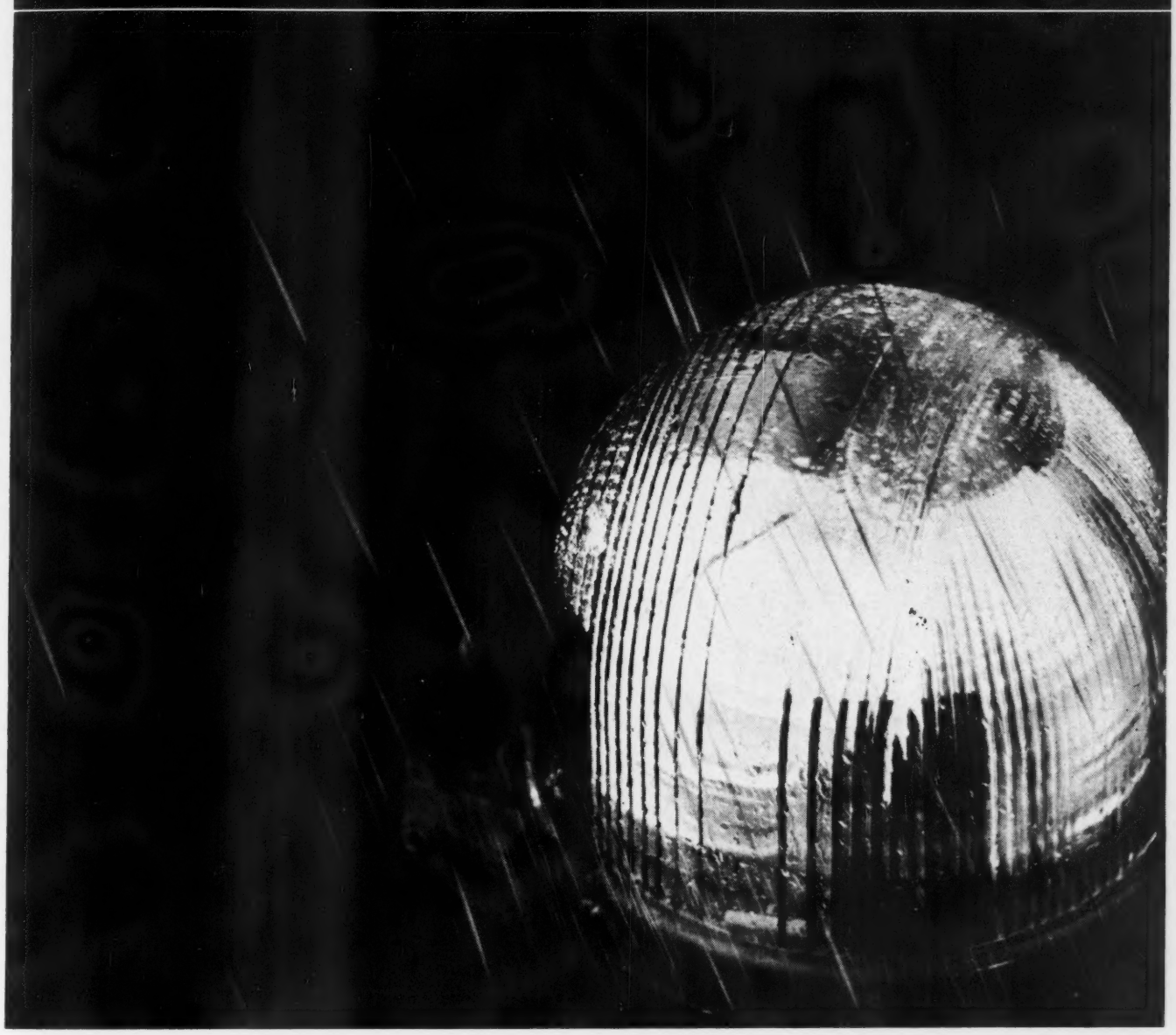
crossed the railroad [5] . . . . . bought a moth preventive [6] . . .

Chances are, you were seeing evidences of Koppers engineering and chemical skills.

1. Koppers chemicals, derived from coal, for use in making certain types of soap. **2.** Koppers chemicals used in making plastic combs. **3.** Koppers American Hammered Piston Rings. **4.** Coke ovens, designed and built by Koppers. **5.** Railroad crossties, pressure-treated by Koppers to resist decay. **6.** Koppers Hex...new, efficient moth protection. Koppers makes all these...and many more useful things besides. All are identified by the Koppers trade-mark, the symbol of a many-sided service. Koppers Company, Inc., Pittsburgh 19, Pa.

K
KOPPERS

The lamps that split "pea soup"...



"ATTENTION, passengers! Fasten your seat belts, please!"

The stewardess stood calmly at the head of the cabin. "Because of adverse flight conditions, we are landing at Newark Airport instead of LaGuardia."

Up in the nose of the plane, the pilot squinted through heavy fog. Slowly he pushed the wheel forward and the plane headed down into the pea soup.

Then he saw them. Tiny pinpoints of clear light, glinting through the thick haze. He guided the plane down between the rows of lights and in a matter of seconds it was safely on the ground.

Flying in pea soup is never easy. But the worst part of it used to be landing in a blinding glare barrage caused by the runway markers lighting up the fog. During the war a leading manufacturer of airport lighting asked Corning to help them design a new runway light that could penetrate any kind of weather without glare. The result was an intricate lamp globe which controls the beam so the pilot sees the light but not the halo.

Corning research has helped aviation in many other ways. Newark's big Bartow air beacon was made from five special glass lenses at Corning. "Black Light" lamps and housings that cause aircraft instrument panels to glow softly at night are all made of Corning glass, as are the little glass jewels in the instruments themselves. Wingtip lights and radio tubes are two more examples.

Altogether we have over 50,000 different glass formulae. Maybe one of them will come to your rescue when you're stewing over some problem in your new job. Make a note now to keep Corning in mind after graduation. Corning Glass Works, Corning, New York.

CORNING
means
Research in Glass

LOOK TO NE
. . . . . to meet today's electrical requirements and those of tomorrow

SINCE 1905

A symbol of quality on wiring systems and fittings for every conceivable requirement.

National Electric
PRODUCTS CORPORATION
Box 897 — Pittsburgh 30, Pa.

THE ROYAL MAIL SHIP

(*Continued from page 331*)

tandem by a single turbine. Each generator room is independent, but they are interconnected through the switchboards, that for the machinery on "E" deck and that for the hotel services on "A" deck. From these main boards, the power mains run to fifty-six auxiliary boards so arranged that each water-tight compartment has its own board. Although the generators develop a maximum of 8,800 kw., in normal operation only three of the four need be run. The emergency generators are located aft on "B" deck. There are two 75 kw. diesel-driven generators to provide power in case of a mishap below. The main circuits are at 220 volts, D.C. For those services which require a lower voltage, a secondary system at 25 volts, D.C., is provided by means of motor generators. A.C. is provided for the wireless by means of alternators.

The steering gear is electro-hydraulic, *i.e.*, electrically driven pumps supply fluid to hydraulic rams which swing the rudder. There are two completely independent systems of rams. The officers on watch can change from the one to the other merely by moving the quarter-master from the wheel which controls the one to the wheel which controls the other. The ship's engines may be used in maneuvering.

In addition to the two wheels which control the steering systems, the navigating bridge has a third for the gyro-compass. The engine controls are also duplicated. Furthermore, the port and starboard wings of the bridge have engine controls, as does the after navigating bridge, but no wheels.

In the accommodations, no effort has been spared for the passengers' comfort and convenience. The ship has theatres, swimming pool, branches of the Midland Bank, and branches of fashionable London shops, as well as the usual garages and kennels, and 37 lifts. In way of accommodation, the ship can carry 2,288 passengers, 822 in First, 668 in Cabin and 798 in Tourist class. The luxury of the accommodations may be better understood from the photographs, which are however all of the First Class, than from a description. (My feeling was that if one did not look over the side now

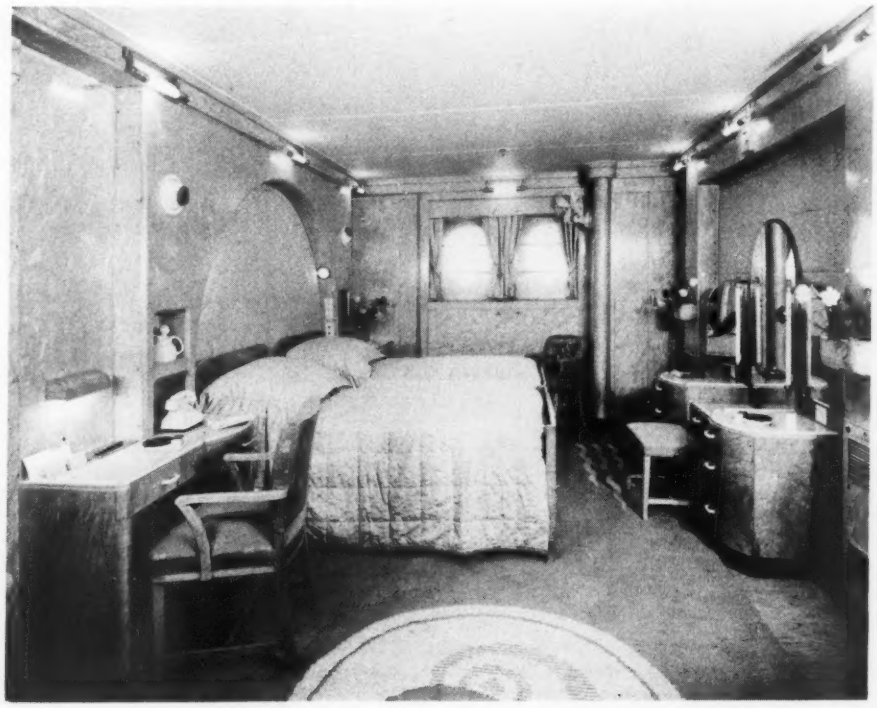
(*Continued on page 348*)

Cunard White Star Ltd.

The forward observation lounge on the promenade deck

Luxury typifies the first-class staterooms

Cunard White Star Ltd.



Measuring fuel performance in the Aircraft Engine Test Cell, Esso Laboratories, Bayway, N. J.

"Prove it!"

Over 2,000 research scientists and technicians are hard at work in the country's most complete petroleum laboratories—the Esso Research Laboratories! Soon the number of these research workers will be upped 20 per cent; soon close to $8,000,000 will be spent to expand those facilities.

These men and these facilities have just one job – *to develop continually finer fuels, lubricants and chemical products from petroleum.*

But their discoveries and their recommendations for improvements must be *tested* and *proved* before they can be put in effect.

That is why, for instance, a half-million-dollar aircraft engine test cell, more modern than any other in America, has been built at the Esso Research Laboratory. Here aircraft engines are run to death, *not* to test the engine – but to test the fuel. This test cell will handle everything up to 3,000 horsepower. And its equipment is the finest throughout – from its vibration-proof control room floated on cork to its 50,000 cubic feet per minute exhaust fan. Controls are electronic, tempered air for carburetion is supplied at 4 in. mercury pressure. Instead of the normal 4 or 5 checks there are 186 points for temperature determination.

Research like this has helped win for Esso products their reputation for quality and dependability.

Esso

UNENDING RESEARCH WORK ASSURES THE HIGH QUALITY OF ALL ESSO PRODUCTS

GAS TURBINES

(*Continued from page 322*)

turbo-jet; and it competes favorably with the reciprocating engine in weight-power ratio.

The basic development problems in the propeller engine are similar to those in the turbo-jet. The engine is complicated by the addition of a gearbox and propeller each of which have problems of their own. Any vibrations caused by the gearbox or propeller may react unfavorably on the remainder of the engine. For instance vibrations arising in the gearbox may have a frequency corresponding to the natural frequency of vibration of one row of compressor blades and cause failure in that row.

Present Status and Future Developments

The gas turbine is no longer a power plant of the future and in the form of the turbo-jet has already many hours of successful use behind it. Its attractions may be summarized as (1) high power for low weight, (2) no vibration, (3) simplicity, (4) small volume, (5) uses relatively simple fuels, (6) low lubricating oil consumption, (7) easy maintenance, (8) no ignition problems, (9) no external cooling problems, (10) easy starting. It can be used with jet, propeller or ducted fan.

The gas turbine is still, however, in the early stages of its development. There are many ideas, such as cooling of turbine blades, which have not yet been applied but which promise to make present-day gas turbines look old-fashioned in a few years time.

Permission to use photographs figures 2 to 10 from Proceedings of the Institution of Mechanical Engineers, Volume War Emergency Issue No. 12, 1945 is gratefully acknowledged. Photograph figure 1 of the Derwent V, the engine with which the current world air speed record was obtained, was supplied by Rolls Royce Ltd. whose courtesy is acknowledged.

TWO-MILLION-VOLT X-RAYS

(*Continued from page 342*)

seen, the higher voltage radiation is clearly superior, due to lower skin dose and lower dose to tissue surrounding the tumor.

Due to relatively low scattering and the presence of the subcutaneous effect, for the same deep tumor dose, the total energy absorbed by the patient is considerably less for two-million-volt radiation than for 200-kv. radiation. This may account for the greater frequency of radiation sickness at the lower voltages.

The irradiation of tumors with x-rays of voltages on the order of several million volts promises to increase the effectiveness with which deep tumors can be treated.

From a report, "Efficient Deep Tumor Irradiation with Roentgen Rays of Several Million Volts" by John G. Trump, Sc.D., Clarence R. Moster, S.B., and Robert W. Cloud, M.S., of the Department of Electrical Engineering of the Massachusetts Institute of Technology.

THE ROYAL MAIL SHIP

(*Continued from page 346*)

and then, one would not realize that one was on a ship.) It might be noted that while austerity is the order in England, the passengers on the *Queen Elizabeth* lack nothing; the food is excellent and the little shops are filled with things to buy.

It may be truthfully said that the *Queen Elizabeth* is the finest of a long line of fine ships which have sailed under the star and lion of Cunard and White Star and under the Union Jack.

The author wishes to express his appreciation to Mr. Mulligan of Cunard White Star Limited, through whose kindness this article has been written and illustrated.

PHYTOHORMONES

(*Continued from page 328*)

internal factor "x" which was the limiting factor if all the other factors had been added. The above named factors are the ones affecting the first two steps in root formation: differentiation of the pericycle cells into root initials and formation of root primordia by these initial cells. However, in order for the root to grow appreciably, nutrients must be present. Another property of root formation was found to be that it is polar only because of the polarity of auxin transport: if auxin is applied to the top of the plant, roots grow there too — and in preference to growth at the base.

Bud inhibition is a phenomenon which one would not associate with the auxins, which are supposed to promote growth. Yet, the fact remains that the mechanism by which lateral buds are inhibited by the terminal bud is in some way activated by auxin: when a terminal bud is cut off and auxin applied at the cut, the lateral buds continue to be inhibited. The concentration of auxin must be several times greater than that coming from the bud, but this situation exists because the auxin is readily destroyed by the enzymes set free in a cut surface. According to one hypothesis explaining the mechanism of bud inhibition, auxin serves to mobilize our old friend factor "x," called caulocaline, which, it would seem, not only promotes root formation but also stem growth. Thus the source of the most auxin production would attract the most caulocaline.

We have been discussing the auxins primarily in this article, but only because they are the hormones about which we know the most; there are many other important plant hormones: For instance, the growth of young leaves is controlled by the hormone adenine which is produced by mature leaves. Moreover, more and more evidence is cropping up supporting the existence of a special flower forming substance. We have already mentioned the auxins, caulocaline, vitamins B_1 and B_6, as well as nicotinic acid. The relation between these hormones is shown graphically on page 323. Furthermore, it is quite possible that there are other plant hormones unknown to us as yet.

At last we come to the crux of our discussion — what is the mechanism by which plant hormones act? Fundamentally we can answer this question in the following way: Most plants — especially the successful ones like tomatoes and wheat — are able to synthesize all their own food up to and including such complex protein nuclei as purine, sterole, imidazole, endole, flavin, pyrimidine, thiazole, etc. However, not each separate part of the plant is able to carry out every synthesis; so each part is dependent on another part for a few necessary compounds and hence is controlled by the rest of the plant (as a matter of interest it might be noted that some plant hormones are also animal vitamins; animals have completely lost synthesizing ability and are therefore completely dependent on plants for their vitamins). We can, in general, best think of the plant as a complex organism unified by the interaction of a number of different hormone compounds in a complex pattern further complicated by the role of nutrients and other external factors.

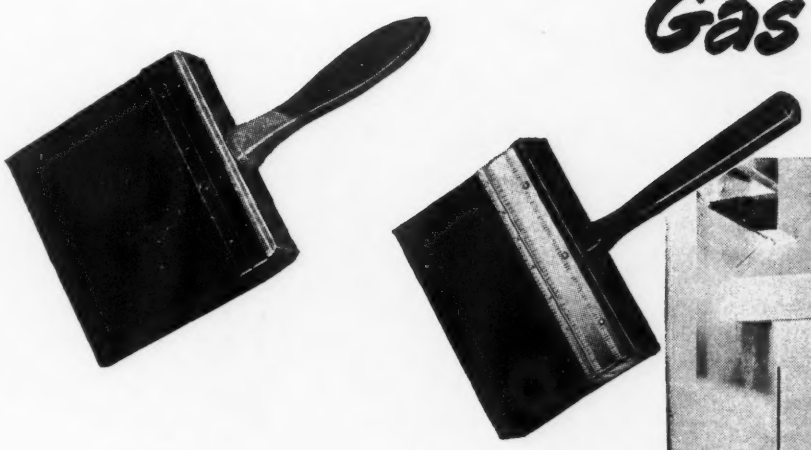
A more definite analysis of the exact role played by each hormone is possible in the case of vitamins B_1, and B_6, etc. For we know fairly completely the role they play in controlling metabolism. However the auxins are the only other plant hormones about which we know enough at present to be able to formulate

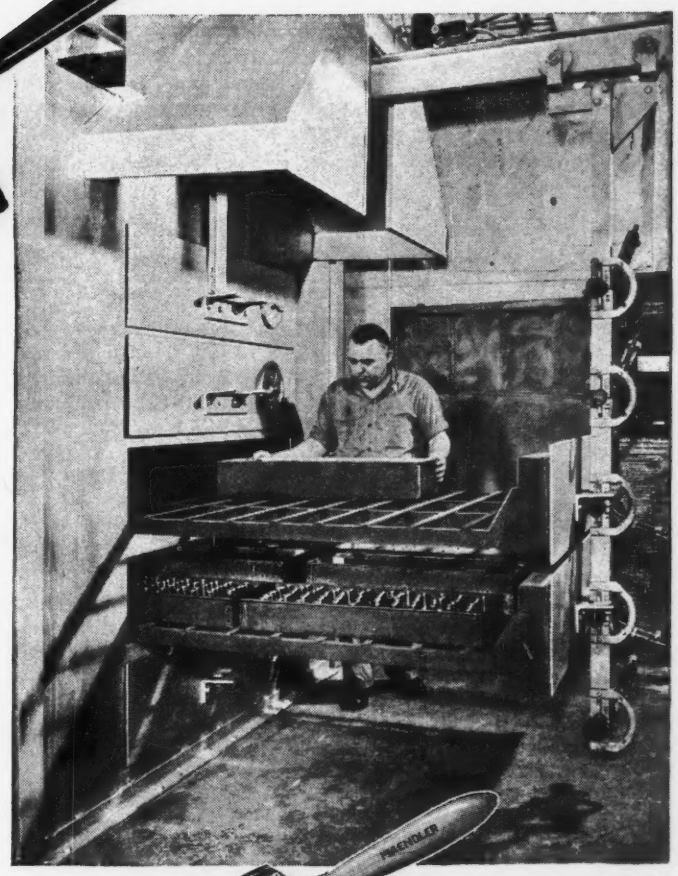
(*Continued on page 350*)

Constant High Quality

with Uniform

Gas heating





Uniform heat, at precise temperatures, assures the constant high quality of Maendler paint brushes. Three automatic, clock-controlled vulcanizing ovens guarantee the exact time-temperature relationship for sealing set-in-rubber bristles; GAS, dependable heat source for toughest industrial heating problems, insures uniform oven temperatures.

The controllability of GAS proved an asset to production at the Maendler plant. By charging the ovens at the end of the normal working day, one extra vulcanizing cycle can be completed after-hours . . . with automatic time and safety controls substituting for the operator.

Efficiency of Gas-Fired Equipment, and economy of GAS for industrial heating, have been demonstrated in thousands of applications as unusual and interesting as this vulcanizing process.

Photo by DESPATCH OVEN COMPANY
Minneapolis, Minnesota

Brushes by MAENDLER BRUSH MANUFACTURING COMPANY, INC., *St. Paul, Minnesota*

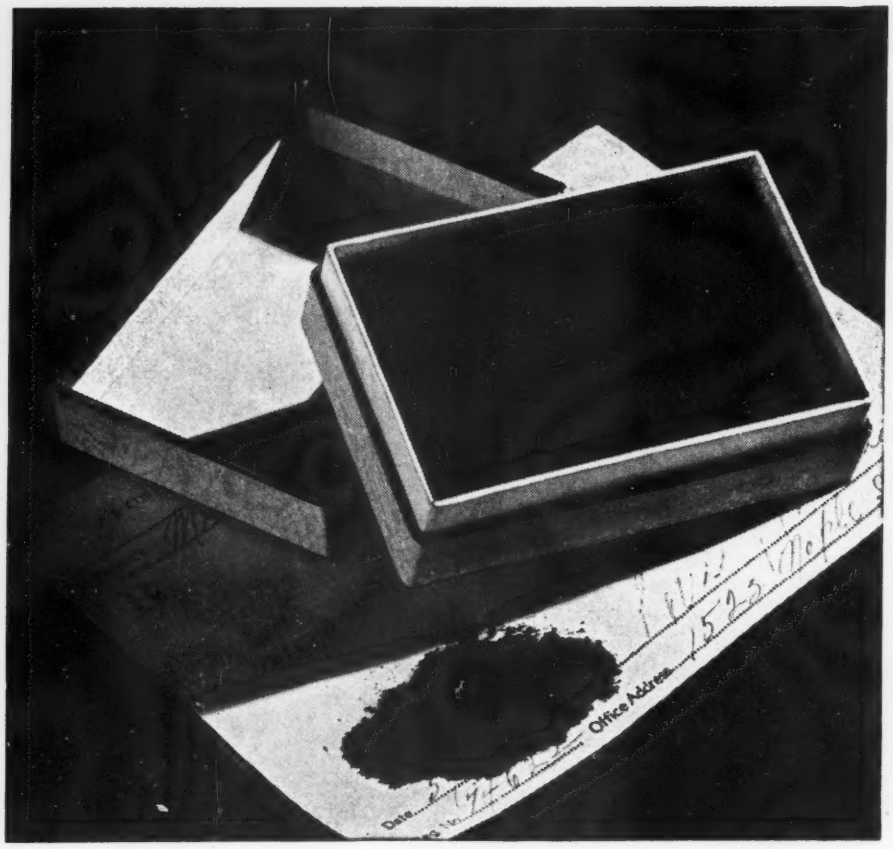
AMERICAN GAS ASSOCIATION

420 LEXINGTON AVE., NEW YORK 17, N. Y.

MORE AND MORE...

THE TREND IS TO GAS

FOR ALL INDUSTRIAL HEATING



Remedy for red ink rash*

*(*for executive use only)*

Say "Ah-h-h," Mr. Executive.

A rash of red ink, hm? Production costs steadily climbing, you say?

Well, there's an effective medication for your troubles—one that will help you cut down those excessive expenses in a hurry.

The prescription? It's called Carboloy Cemented Carbide—*the hardest metal made by man.* Formed from the powder you see pictured into blanks for tools, dies and wear-resisting parts, Carboloy * is the greatest single factor for reducing manufacturing costs that modern industry has ever known, BECAUSE:

1. **Carboloy commonly *triples the output* of both men and machines,**
2. **Regularly increases the quality of products, and**
3. **Cuts, forms or draws the toughest, most abrasive modern alloys with accuracy and speed previously unknown.**

That is why Carboloy is held by authorities to be *one of the ten most important industrial developments of the past decade.*

We Make This Challenge

The odds are 10 to 1 that Carboloy—the amazing metal of many uses—can be put to work by our engineers to give your products higher quality at lower cost. Call us in for consultation.

Carboloy Company, Inc., Detroit 32, Mich.

CARBOLOY

*(TRADE MARK) CEMENTED CARBIDE

THE HARDEST METAL MADE BY MAN

PHYTOHORMONES

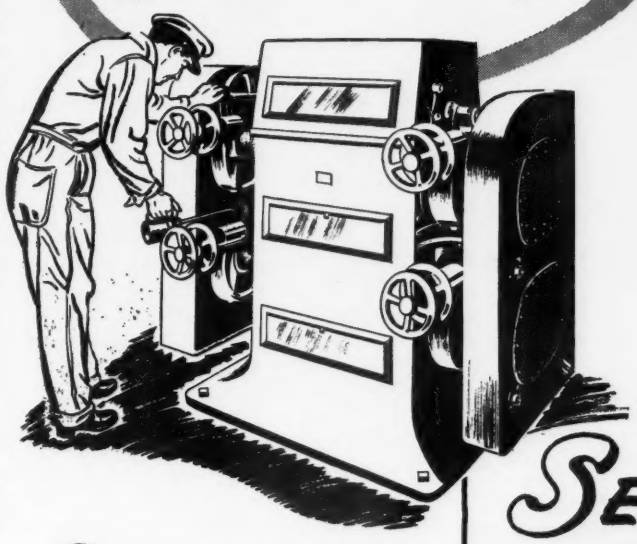
(*Continued from page 348*)

acceptable theories of the mechanism through which they act. The cell wall was regarded for a long time as the structure which was most influenced by the auxins: it was believed that the cell wall was made plastic and hence amenable to expansion by auxin action. Of course, it was known that auxin increased the rate of cell division in the cambium, but it was argued, and rightly so, that plants grow primarily by cell elongation, not cell division. However, there was shown to be no stoichiometric ratio between intake of auxin and any material present in the cell wall; so, since it is believed that auxin does not produce a general stimulus but rather enters into a specific chemical reaction in the plant, the viewpoint of cell wall transformation has been to some extent abandoned. Another theory was that auxin mobilized the other necessary factors at the site of growth; however, it was shown that auxin produced a normal effect even when the growing part was completely surrounded by all the needed factors. One interesting phenomenon which is explained by no theory is the effect auxin has in increasing the rate of streaming of protoplasm.

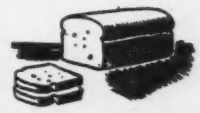
At this point it would be well to consider auxin from the chemical rather than the physiological point of view in order to determine why it is considered that auxin has a specific chemical effect. At first, when it was observed that a great number of different substances acted as auxins, the role of auxin was conceived as being a very general sort of stimulus. However when the auxins were examined more closely it was seen that all had certain properties in common: (*a*) an unsaturated or aromatic ring; (*b*) a carboxyl group, or a group readily hydrolyzable into a carboxyl group, in the side chain; and (*c*) a special configuration between the carboxyl group and the ring. Furthermore, it is possible to explain the apparently different molar activities of the auxins on the basis of different secondary characteristics; *i.e.*, different rates of transport, different abilities to prepare the cells for the actual growth reaction. Hence we can see that from a chemical point of view the auxins should have a definite common chemical effect. And, since the auxins enter into so many different types of growth phenomena it would seem likely that the role of auxin is to enter into some basic chemical reaction which would have

(*Continued on page 352*)

UNLOCKING SECRETS OF THE SOY BEAN..



THE SOY BEAN, ONCE PLANTED ONLY AS A ROTATION CROP, WAS PLOWED UNDER TO INCREASE THE FERTILITY OF THE SOIL.



THEN SCIENCE DISCOVERED THAT SOY BEAN FLOUR IS WHOLESOME ...THE OIL MAKES GOOD PAINTS AND SALAD DRESSING... THE MEAL IS GOOD CATTLE FEED... THE FIBRE MAKES PLASTICS.. BUT FIRST EXTRACTION METHODS DIDN'T GET ALL THE OIL...ONLY PARTIALLY SEPARATED THE OTHER INGREDIENTS.

SENSATIONAL NEW OIL EXTRACTION METHOD DEVELOPED BY A-C SCIENTISTS

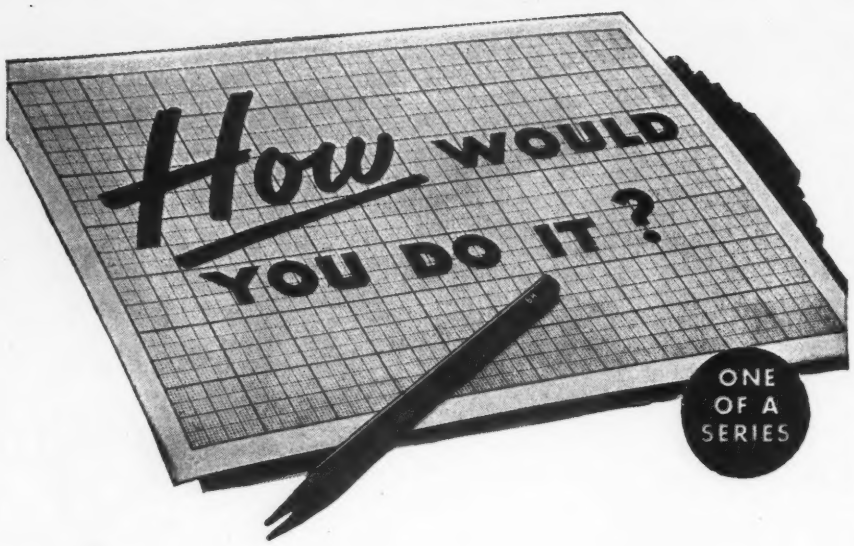
REVOLUTIONARY SOLVENT EXTRACTION MACHINERY NOW SEPARATES SOY BEAN OIL, PULP AND MEAL EFFICIENTLY—AT LOW COST AND EXTENDED USE OF THIS EQUIPMENT IS INCREASING THE YIELD FROM OTHER OIL-BEARING MATERIALS SUCH AS FLAXSEED, COTTON SEED, COPRA, PALM KERNELS, PEANUTS AND MEAT SCRAPS.....

90% OF ALL SOY BEAN MILLING TODAY IS DONE WITH A-C EQUIPMENT. THIS WORK THAT ALLIS-CHALMERS HAS DONE WITH SOY BEANS GOES ALL THE WAY FROM PLANTING AND HARVESTING THROUGH MILLING AND PROCESSING. IT IS TYPICAL OF THE ENGINEERING AID A-C OFFERS TO EVERY BASIC U.S. INDUSTRY.

ALLIS-CHALMERS MANUFACTURING COMPANY, MILWAUKEE 1, WISCONSIN

ALLIS CHALMERS

ONE OF THE BIG 3 IN ELECTRIC POWER EQUIPMENT
BIGGEST OF ALL IN RANGE OF INDUSTRIAL PRODUCTS



PROBLEM—Every so often, as the commutator segments of large motors wear down, the mica between them must be cut down. Your problem is to work out a tool which permits the undercutting to be done without removing the armatures from the motors.

THE SIMPLE ANSWER—An S.S.White power drive flexible shaft hooked up to an electric motor gives you the basis of a portable power unit for driving small rotary saws. A handpiece designed for mounting the saws finishes the tool.

The time and labor-saving advantages of having an easily manipulated power tool which can be brought to the work, can be readily appreciated. S.S.White flexible shafts make practicable the development of such tools for many purposes.

★ ★ ★

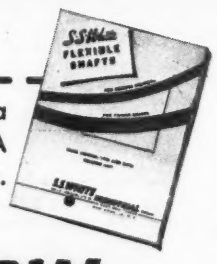
This is just one of hundreds of power drive and remote control problems to which S.S. White flexible shafts provide a simple answer. Engineers will find it worth while to be familiar with the range and scope of these *Metal Muscles* * for mechanical bodies.

Here's how the Martindale Electric Co., of Cleveland, Ohio, does it with a 1/4 hp. motor and flexible shaft combination.

* Trade Mark Reg. U.S. Pat. Off. and elsewhere

WRITE FOR BULLETIN 4501— - - - -

It gives essential facts and engineering data about flexible shafts and their application. A copy is yours free for the asking. Write today.



S.S.WHITE INDUSTRIAL DIVISION

THE S. S. WHITE DENTAL MFG. CO. DEPT. C, 10 EAST 40th ST., NEW YORK 16, N. Y.

FLEXIBLE SHAFTS • FLEXIBLE SHAFT TOOLS • AIRCRAFT ACCESSORIES
SMALL CUTTING AND GRINDING TOOLS • SPECIAL FORMULA RUBBERS
MOLDED RUBBERS • PLASTIC SPECIALTIES • CONTRACT PLASTICS MOLDING

One of America's AAAA Industrial Enterprises

PHYTOHORMONES

(*Continued from page 350*)

different effects depending on the nature of the cells and other factors present. This theory has received much support from the important discovery of Thimann and co-workers that auxin enters into reactions which account for about ten per cent of the respiration, and hence the energy, of most of the plants studied. It was also observed that the four carbon acids — malic, fumaric, succinic, and the three carbon acid, pyruvic, are essential to the reaction. Furthermore other experiments have indicated that the growth of plants consists essentially, not of increase in dry weight, but of increase in volume brought about by the absorption of water and some salts. Therefore it seems quite likely that the rôle of auxin as a growth promoting substance is to act as a co-enzyme in a respiratory system, controlled by the four carbon acids, which system releases the energy necessary to absorb water for growth and which somehow brings about acceleration of the little understood phenomenon of protoplasmic streaming.

Theory has been the backbone of our discussion so far, but we must not assume that this pure research in plant hormones has yielded no practical results. We have already mentioned the production of parthenocarpic or seedless fruit, which is made possible by artificially supplying to unfertilized fruit the auxin which normally comes from the seeds. Another application of auxins is in the spraying of fruit on trees to prevent premature dropping, for auxin retards the division of the petiole cells which hold the fruit to the tree. Other applications result from the toxicity of high concentration of auxins. Last year New York City took sprayers from watering equipment and helped out allergy victims by killing ragweed with auxin spray. In Puerto Rico and other sugar producing areas auxin is rapidly becoming invaluable in killing bind weed, and auxin will undoubtedly find use in killing many other weeds, especially since it will kill dandelions and such plants without hurting the surrounding grass.

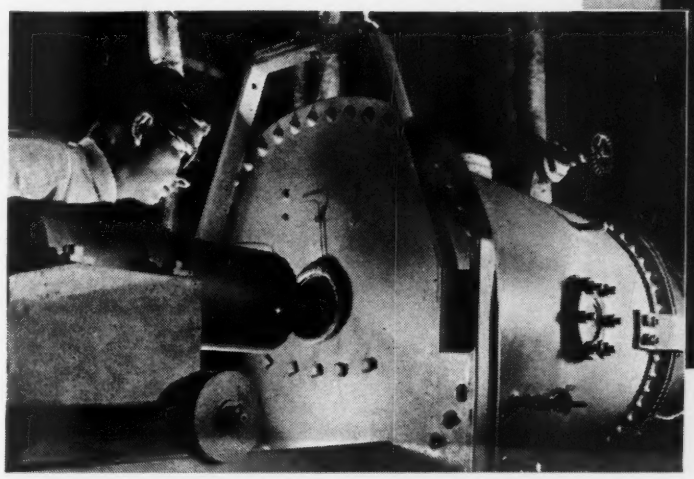
We can see that all this theoretical work in the plant hormones — interesting enough for its own sake — has been of great practical value, and will in the future probably bring about a great deal of important development in the field of plant engineering — the application of scientific methods to farming and horticulture.

Du Pont *Digest*

Items of Interest to Students of Science and Engineering

Explosives—an essential industrial tool

A. L. St. Peter, Princeton '37, supervisor blasting operation Susquehanna River Project, lowers a 5½ inch "Nitramon" Primer into one of 600 drill holes preparatory to blasting a pipe line ditch.



Frank A. Loving, Chemical Engineer, Texas A & M '41, prepares to fire an explosive charge into a chamber of methane or dusty air to test safety under conditions found in coal mines.

INDUSTRIAL explosives are as much of a yardstick of industrial progress as sulfuric acid. They are involved in the fabrication of nearly all the products used by man. This year the United States will use over 500 million pounds of industrial explosives.

The technical problems that confront the explosives industry are many and varied. A measure of this is the fact that the Du Pont Company manufactures about two hundred dynamite formulations, each intended to do a different job, from the slow heaving action of blasting coal to the rapid, violent shattering necessary for a hard ore. Ranging between these two extremes are a large number of intermediate grades, including explosives especially formulated for agricultural work, seismic prospecting for oil, submarine blasting—right down to the tiny charge used in an explosive rivet.

Studies in Laboratory and Field

One of the first industrial laboratories for chemical research in the United States, the Eastern laboratory of the Du Pont Explosives Department has nearly two hundred chemists, engineers, physicists and assistants. There, methods have been developed for measuring the power of explosives, the degree to which they shatter or pulverize various materials, their water resistance, their safety characteristics when exposed to shock or flame, the composition of the gases they produce, etc. As a result of studies of the influence of various factors on dynamite performance, it has become possible to formulate an explosive to meet practically any blasting condition.

In keeping with these improvements, the application of explosives has reached a new level of efficiency. Technical service men, usually mining engineers or civil engineers, aid consumers in the selection and use of explosives. They also work closely with research men in solving unusual problems encountered in the field.

Research—Path to Progress

A few of the results gained through research are: (1) lowering of dynamite freezing points by nitrating ethylene glycol along with glycerol to diminish the hazards of thawing frozen dynamites. (2) Production of less hazardous dynamites by substituting ammonium nitrate partially for nitroglycerine, in spite of the greater hygroscopicity and lesser explosive power of the former. This resulted in dynamites less hazardous to manufacture and use. (3) Introduction of "Nitramon," a blasting agent containing a high percentage of ammonium nitrate as its major ingredient. It is equal in strength to the most powerful dynamites commonly employed and yet is by far the safest blasting agent available. (4) Development of explosives with a minimum of noxious gases for use in confined areas. (5) Numerous improvements in the composition, manufacture and design of the blasting caps which set off the main charge.

Aside from these developments in explosives and blasting supplies, there have been many accomplishments in chemistry and engineering associated with such projects as the oxidation of ammonia to nitric acid; manufacture, granulation and drying of ammonium nitrate; substitutes for nitroglycerine and ethylene glycol dinitrate, concentration of nitric and sulfuric acids, and a host of other subjects.

Questions College Men ask about working with Du Pont

WHAT ARE THE OPPORTUNITIES FOR RESEARCH MEN?

Unusual advantages in facilities and funds are available to men qualified for fundamental or applied research. Investigation in the fields of organic, inorganic and physical chemistry, biology, parisitology, plant pathology and engineering suggest the wide range of activities. Write for booklet, "The Du Pont Company and the College Graduate," 2521 Nemours Building, Wilmington 98, Delaware.

DU PONT
REG. U. S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING
...THROUGH CHEMISTRY

More facts about Du Pont—Listen to "Cavalcade of America," Mondays, 8 P.M. EDST, on NBC

THE TECH ENGINEERING NEWS INDEX

VOLUME XXVIII

	Month	Page
"And in the Wake of the Giants Came the Little People." *Peter B. Neiman, '49*	Mar. 1947	233
"And the Lesser Light to Rule the Night." *Peter B. Neiman, '49*	Feb. 1947	193
Automotive Chemicals, Part I *Alvin J. Siteman, '48*	Oct. 1946	19
Automotive Chemicals, Part II *Alvin J. Siteman, '48*	Nov. 1946	65
Bikini Allows Thirty Seconds. *Joseph M. Rault, Jr., '48*	Dec. 1946	107
Birth of the Planets, The. *Peter B. Neiman, '49*	May 1947	323
Chemicals from Petroleum. *Harold Conroy, '48*	Feb. 1947	185
Christmas Star, The. *Peter B. Neiman, '49*	Dec. 1946	101
Color Photography, Part I *Kenneth Wiberg, '48*	Dec. 1946	102
Color Photography, Part II. *Kenneth Wiberg, '48*	Jan. 1947	153
Color Television. *Richard W. Spencer, '49*	Mar. 1947	225
Compounds of the Rare Gases, The. *Lee Hanower, '47*	Nov. 1946	59
CONROY, HAROLD, '48		
Chemicals from Petroleum	Feb. 1947	185
Isotopes for Sale	Mar. 1947	230
Cosmic Ray Phenomena. *Harrison White, '50*	Jan. 1947	148
DAVIS, ROBERT B., 10-'46		
Of Men and Mice	Oct. 1946	21
Well, What Happened to You?	Nov. 1946	61
EATON, FLETCHER, '49		
Evolution of an Airplane, Part II	April 1947	273
Modern Aircraft Manufacture	Dec. 1946	97
Evolution of an Airplane, Part II. *Fletcher Eaton, '49*	April 1947	273
Experiment in Industry, An. *Edward M. Kosower, '48*	Oct. 1946	16
Fluid Catalysts. *Rodman Jenkins, 10-'46*	Oct. 1946	23
Food Technology. *Leo Sartori, '50*	April 1947	281
FRASSINELLI, GUIDO J., '48		
XB-35, Giant Wing	Nov. 1946	57
FRIEDMAN, LESTER		
Molecules of Life	Feb. 1947	190
Future of Industry in the Philippine Islands, The. *Pedro Picornell, '47*	Dec. 1946	105
Gas Turbines. *Professor William Hawthorne*	May 1947	319
German Wartime Industrial Developments. *Edward A. Mullery, '48*	Dec. 1946	100
GIORI, FRANCIS A., '45		
Micro-Pulse Radio-Telegraphy	Oct. 1946	13
"Greater Light to Rule the Day . . . , The" *Peter B. Neiman, '49*	April 1947	285
HANOWER, LEE, '47		
Compounds of the Rare Gases, The	Nov. 1946	56
HAWTHORNE, WILLIAM, Associate Professor of Mechanical Engineering		
Gas Turbines	May 1947	319
Heating by Refrigeration. *Richard W. Spencer, '49*	April 1947	278
Home of the Volkswagen. *Henry L. Lee, '47*	Nov. 1946	67
Hydrides — Compounds of the Future, The. *Harrison White, '50*	Mar. 1947	228
Isotopes for Sale. *Harold Conroy, '48*	Mar. 1947	230
JENKINS, RODMAN, 10-'46		
Fluid Catalysts	Oct. 1946	23
JENKINS, ROY M., '50		
John Hancock Builds a New Home	Mar. 1947	237
John Hancock Builds a New Home. *Roy W. Jenkins, '50*	Mar. 1947	237
JOHNSON, PETER, '48		
The Radio Society of M. I. T.	Jan. 1947	151
KOSOWER, EDWARD M., '48		
An Experiment in Industry	Oct. 1946	16
KURINSKY, HERBERT, '48		
Vacuum Engineering	Feb. 1947	194
LEE, HENRY L., '47		
Home of the Volkswagen	Nov. 1946	67
Micro-Pulse Radio-Telegraphy. *Francis A. Giori, '45*	Oct. 1946	13
MILLER, EDWARD T., '49		
Navar	Jan. 1947	145
Modern Aircraft Manufacture. *Fletcher Eaton, '49*	Dec. 1946	97
Molecules of Life. *Lester Friedman*	Feb. 1947	190
MULLERY, EDWARD A., '48		
German Wartime Industrial Developments	Dec. 1946	100
Navaglobe. *Richard W. Spencer, '49*	Feb. 1947	188
Navar. *Edward T. Miller, '49*	Jan. 1947	145

THE TECH ENGINEERING NEWS INDEX (Continued)

	Month	Page
NEIMAN, PETER B., '49		
"And in the Wake of the Giants Came the Little People"	Mar. 1947	233
". . . And the Lesser Light to Rule the Night"	Feb. 1947	193
Birth of the Planets, The	May 1947	323
Christmas Star, The	Dec. 1946	101
Stars or Planets?	Nov. 1946	64
"The Greater Light to Rule the Day . . ."	April 1947	285
The Sun's Sons	Jan. 1947	155
New Comfort on the Rails. *John W. Weil, '48*	Oct. 1946	9
Of Men and Mice. *Robert B. Davis, 10-'46*	Oct. 1946	21
PICORNELL, PEDRO, '47		
The Future of Industry in the Philippine Islands	Dec. 1946	105
Phytohormones. *Harrison White, '50*	May 1947	324
Radio Society of M. I. T., The. *Peter Johnson, '48*	Jan. 1947	151
RAULT, JOSEPH M., '48		
Bikini Allows Thirty Seconds	Dec. 1946	107
Royal Mail Ship *Queen Elizabeth*, The. *George Swallow, '48*	May 1947	329
SARTORI, LEO, '50		
Food Technology	April 1947	281
SITEMAN, ALVIN J., '48		
Automotive Chemicals, Part I	Oct. 1946	19
Automotive Chemicals, Part II	Nov. 1946	65
SMITH, SIDNEY L., '47		
Your Supper — Minus Water	Mar. 1947	234
Sun's Sons, The. *Peter B. Neiman, '48*	Jan. 1947	155
SPENCER, RICHARD W., '49		
Color Television	Mar. 1947	225
Heating by Refrigeration	April 1947	278
SPENCER, RICHARD W., '49 (*Continued*)		
Navaglobe	Feb. 1947	188
Two-Million Volt X-Rays in the Treatment of Cancer	May 1947	317
Stars or Planets? *Peter B. Neiman, '49*	Nov. 1946	64
SWALLOW, GEORGE, '48		
The Royal Mail Ship *Queen Elizabeth*	May 1947	329
Two-Million Volt X-Rays in the Treatment of Cancer. *Richard W. Spencer, '49*	May 1947	317
Vacuum Engineering. *Herbert Kurinsky, '48*	Feb. 1947	194
WEIL, JOHN W., '48		
New Comfort on the Rails	Oct. 1947	9
Well, What Happened to You? *Robert B. Davis, 10-'46*	Nov. 1946	61
WHITE, HARRISON, '50		
Cosmic Ray Phenomena	Jan. 1947	148
Hydrides — Compounds of the Future	Mar. 1947	228
Phytohormones	May 1947	324
WIBERG, KENNETH, '48		
Color Photography, Part I	Dec. 1946	102
Color Photography, Part II	Jan. 1947	153
WMIT — The Beaver Network. *WMIT Staff*	April 1947	283
WMIT STAFF		
WMIT — The Beaver Network	April 1947	283
XB-35, Giant Wing. *Guido J. Frassinelli, '48*	Nov. 1946	57
Your Supper — Minus Water. *Sidney L. Smith, '47*	Mar. 1947	234

FEATURES	Month	Page
THE DRAGON'S DEN		
J. W. W.		
Attention E.C.M.A. Editors and all Students . . .	Nov. 1946	75
Editorial	Oct. 1946	29
E. M. K.		
E Pluribus Unum . . .	Mar. 1947	243
For a Brave New World . . .	Dec. 1946	117
Life, Liberty, and the Pursuits of Engineers . . .	Feb. 1947	199
Opportunity Knocks	April 1947	289
Progress . . .	May 1947	335
Why Not More Scientists? . . .	Jan. 1947	159
CAN YOU DO IT? J. W. W.		
A Couple of Problems that Look Deceptively Easy . . .	Nov. 1946	74
A Couple of the Old Classics — one easy and one hard!	Dec. 1946	116
A Pair of Unique Problems . . .	May 1947	334
Four of the Classics — All Easy!	Feb. 1947	198
Three Miscellaneous Gems . . .	Mar. 1947	242
Two Easy Ones — but look before you leap!	Jan. 1947	158
Two New Ones — one elementary and one advanced . . .	April 1947	288
BRIEFING THE NEWS	Oct. 1946	4
	Jan. 1947	140
	Feb. 1947	180
	Mar. 1947	220
	April 1947	268
	May 1947	312

Another Reason *for* Norton Leadership . . .

RESEARCH

IT WAS an *idea* plus the spirit of experimentation that led to the development of a grinding wheel in F. B. Norton's pottery shop in 1877. That same pioneering spirit led to many other important Norton contributions to industry during the succeeding 70 years. In 1946 it resulted in 32 ALUNDUM abrasive—the sensational new aluminum oxide abrasive made by a unique electric furnace process.

Today the Norton research laboratories at Worcester and at the Chippawa electric furnace plant occupy 75,000 square feet of floor space, are equipped with the most modern apparatus and have a staff of over 135 skilled scientists and technicians. Included are:

Mechanical Engineers	Physical Chemists
Electrical Engineers	Organic Chemists
Ceramic Engineers	Electro-chemists
Chemical Engineers	Metallurgists
Petrographers	Physicists

The teamwork of this group has had much to do in making Norton the unquestioned leader in the abrasive industry.

NORTON COMPANY
Worcester 6, Mass.

1877 — F. B. Norton patented a new grinding wheel (emery bonded by the vitrified process).

1893 — Grinding wheels of natural Corundum.

1897 — India oilstone.

1900 — First production-precision grinding machine.

1901 — First manufactured aluminum oxide abrasive — ALUNDUM®

1904 — Water-cooled electric furnace revolutionized production of Alundum abrasives.

1910 — 38 Alundum abrasive—white aluminum oxide of exceedingly high purity.

1911 — High temperature refractory products.

1917 — Efficient non-slip wear-resisting floors.

1921 — Pulpstone for grinding pulp wood for newsprint.

1924 — Porous diffuser plates for sewage disposal plants.

1930 — First diamond grinding wheels (resinoid bonded).

1930 — Controlled structure method of grinding wheel manufacture.

1934 — Norbide abrasive and molded products — Norton boron carbide, hardest known substance except the diamond.

1935 — Electrical periclase — a refractory electrical insulator for heating units.

1936 — First metal bonded diamond wheels.

1938 — Optical resin — a hard, transparent, water-white resin.

1942 — First vitrified bonded diamond wheels.

1945 — Pure oxide refractories — for temperatures above 1800° Centigrade.

1946 — 32 ALUNDUM

NORTON

ABRASIVES — GRINDING WHEELS — GRINDING AND LAPPING MACHINES
REFRACTORIES — POROUS MEDIUMS — NON-SLIP FLOORS — NORBIDE PRODUCTS
LABELING MACHINES (BEHR-MANNING DIVISION: COATED ABRASIVES AND SHARPENING STONES)

BIRTH OF PLANETS

(*Continued from page 323*)

the accelerations produced by S' in P and P'. The sides PD and $P'D'$ will then represent the perturbative action, and since $PA > SB > P'A'$, PD must be directed toward a point between S and S' while $P'D'$ is directed to a point beyond S. That is, the action of S' in its new position is to give to the matter earlier ejected from S an angular momentum in the direction of the orbital motion of S'. S' moved rapidly away from the scene of action and is now lost from view; and P and P' were left revolving in elliptical orbits under the attraction of the sun.

As S' swung around the sun, material was ejected from S at frequent intervals or continuously, and all the particles were acted upon in the way described above but in different directions and by different amounts. In figure 2 the curves S_1 and S_1' represent the paths followed by the particles P and P', and the curves S_2 and S_2' S_3 and S_3' . . . represent the paths followed by particles which were ejected later. The dotted ellipse is the orbit finally pursued by particle No. 3 after S' had receded so far that its influence was no longer important.

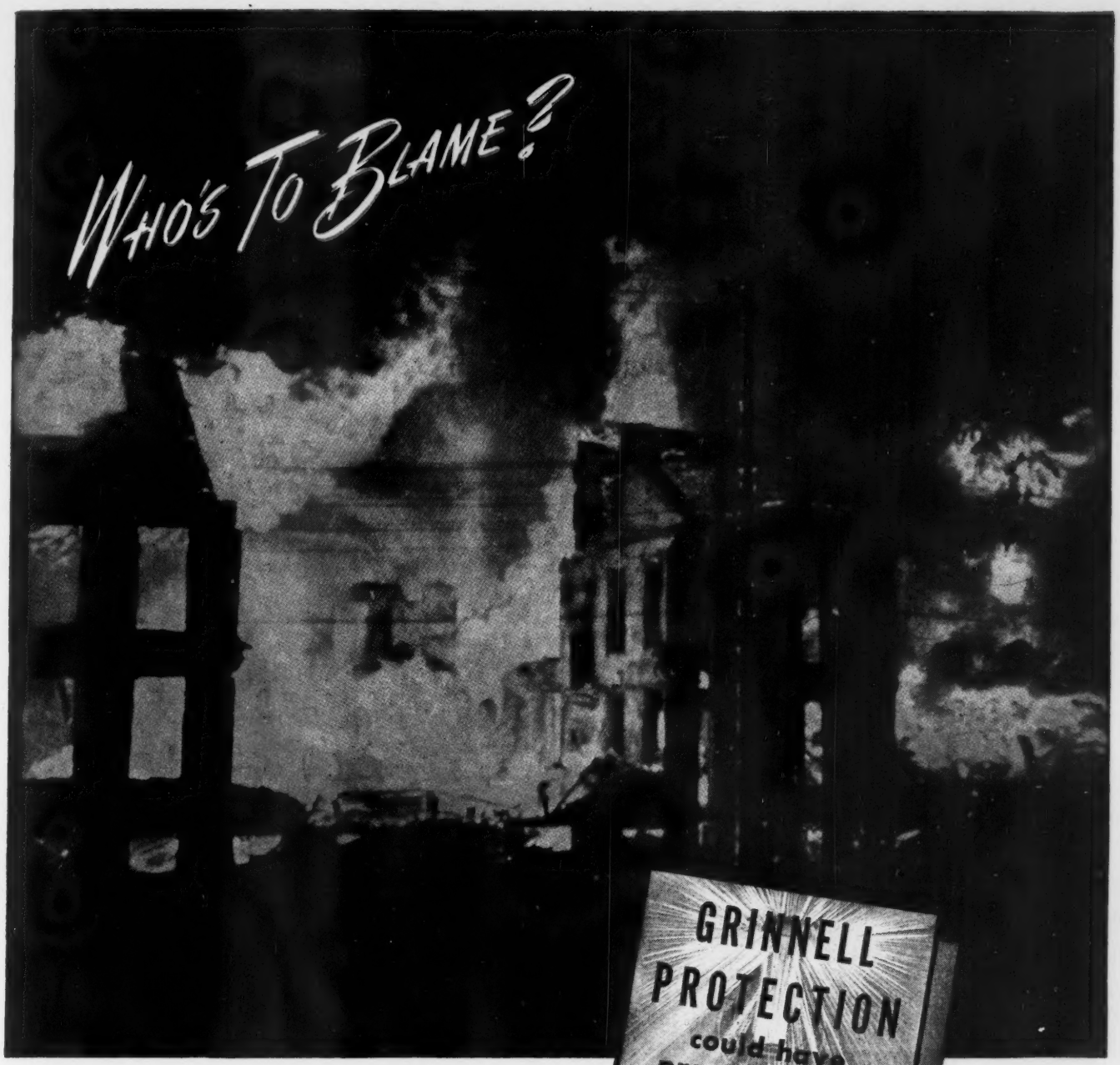
Finally, there is the Jeans Tidal Theory. By drawing the planets side by side (figure 3) and in their relative sizes, it is seen that the envelope of these spheres is a cigar-shaped curve. If an approaching star had caused a tidal action on the sun, which would release a long filament of gaseous matter, which eventually condensed into spherical bodies, the result would be comparable to the present cigar-like envelope of the planets, with the largest bodies being in the center, where the star came closest to the sun, and thinning out in each direction, as the star approached and receded from it. Since these bodies were still plastic, they too would receive tidal action as they subsequently approached perihelion passage in their orbits about the sun, with the satellites of the planets, such as the moon, thus being born.

These, then are the main theories of the birth of the planets. What they lack in scientific proof is balanced by the influence that they can exert upon man's thoughts, for if he can determine where he has come from, and how he has arrived, it is not inconceivable that he might determine where he may be going.

---

[1] Op. cit., P. 347.

[2] Diagrams and explanatory matter from *Astronomy*, J. C. Duncan, Pp. 314-15.



CHALK IT UP TO A CARELESS MAN with a match. But don't fool yourself. If your properties suffer material damage by fire the truly careless man will be *you*—for as long as people are human and thoughtless, fires will start, but as long as there is Grinnell Protection you can control these fires quickly, effectively, at the source.

So the choice is actually your own—whether you risk your property to swell the present $500,000,000 annual destruction by fire—or whether you safely join the group of those owning over seventy billion dollars worth of property who have prepared for fire, who have cut losses to trifling amounts with Grinnell Protection.

There is a system of Grinnell Protection for every kind of fire hazard, ready to stop fire immediately wherever it strikes. If your property is unprotected against fire you're *paying* for Grinnell Protection—*why not have it?* Grinnell Company, Inc., Providence 1, R. I. Branch Offices in Principal Cities.

GRINNELL

FOUNDED 1850

Automatic Fire Protection Systems

UNIVERSITY
347
LIBRARY

Campus to GENERAL ELECTRIC

TOMORROW'S APPLIANCES

The Story of

JIM YOUNG

THE General Electric refrigerators, ranges, washers and other appliances that homemakers will be buyng in 1950 are already under development. James F. Young, ten years out of Lafayette College's mechanical engineering school, supervises the engineering of these appliances-to-come.

Jim, graduating magna cum laude, chose General Electric's job offer over others because, as he says, "G.E. offered more different fields of engineering, had a better program than any other company, and could provide better experience."

The varied experience that Jim sought came to him fast. While on "Test" with G.E., he worked in four different plants and at six different assignments, ranging from supercharger tests to studies in unbalance of hydraulic systems. Following "Test" he enrolled in the G-E Creative Engineering Program and drew five assignments in laboratories and design departments.

When he had completed the course he was appointed supervisor of it. While organizing this course and lecturing to the class, he studied another—the C course in mechanical engineering. He also wrote and edited "Materials and Processes," published in 1944.

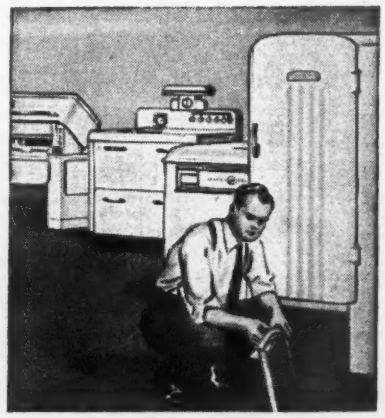
His first "real work," he says, was in helping to develop large-size rocket launchers, both airborne and land types. The creative engineering ability he showed on this assignment, and on later problems, insured his steady progress to the top of the Advance Engineering Section of his company's Appliance and Merchandise Dept.

Next to schools and the U.S. Government, General Electric employs more college engineering graduates than any other organization.

Jim became interested in mechanical problems early. In his teens he found a hobby in rebuilding old autos.

As an early job with G.E. he organized and taught engineering courses, became supervisor of all mechanical engineering training.

During the war he helped develop the airborne rocket launcher, important factor in smashing Nazi armor. A second war job: development of gyroscopes for torpedoes.



Today Jim supervises the engineering of G-E household appliances to be marketed two to five years from now. He still directs the training of many new engineers.

GENERAL ELECTRIC

The Murray Printing Company
Cambridge, Massachusetts